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# ARTILLERY SYSTEMS ENGINEERING STUDY (CONCEPT TEAM FINAL REPORT)



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JULY 1981

US ARMY ARMAMENT RESEARCH AND DEVELOPMENT COMMAND
LARGE CALIBER
WEAPON SYSTEMS LABORATORY
DOVER, NEW JERSEY

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An engineering study is undertaken to depict large caliber battery weapon concepts for battlefield employment within the next 10 years. Among the self-propelled systems proposed are casemate, turreted, and enhanced M109A2 designs and two foreign systems. Included are companion vehicles for ammunition re-supply and battery fire control. Ammunition concepts include scatterable mines, fire-and-forget cannon-launched guided projectiles, and extended range. In addition, numerous special subjects such as antitank projectiles, reliability availability and maintainability considerations, alternate ammunition (cont)

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20 ABSTRACT (cont)

handling concepts, weapon stability at high rates of fire, communication and data transmission requirements, and reduction of delivery error are discussed.

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# INTRODUCTION

The concept generation task documented by this report was part of the artillery system engineering study (ASES), and was accomplished prior to the contractual effort for the concept formulation phase of the enhanced self-propelled artillery weapon system (ESPAWS) program. The concept team worked closely with the technology assessment and system analysis teams, all of which made up the artillery system engineering working group (ASEWG).

The general plan for the ASEWG was for the concept team to develop battery weapon systems concepts based upon:

a. Inputs from previous and related system analysis efforts.

b. Technology inputs from the technology team.

c. Threat information.

Each battery concept included the following subsystems:

a. Self-propelled howitzer (SPH) and all of its on-board equipment.

b. Family of munitions.

c. Ammunition resupply back to the ammunition supply point (ASP)/ammunition transfer point (ATP).

d. Battery fire direction center (FDC).

This conceptual effort was the first step in a process which will be followed by an intensive and much larger contractural effort for ESPAWS, and which will lead to an Army Systems Acquisition Review Council I (ASARC I). The approach taken was to generate "order of magnitude" concepts. In general, enough design details were developed to define the concepts so that design and performance characteristics could be established. The key point was to develop reasonable performance characteristics so that they could be fed into systems analysis models in order to evaluate overall systems effectiveness and to compare concepts against the baseline system.

The amount of detail and refinement to be provided was time dependent. (During this phase, extensive detail was not necessary since the concepts were "first-cut" efforts). If time had permitted, refinement would have been desirable following the systems analysis efforts in order to determine which class of concepts had the highest payoff. However, the follow-on conceptual effort could probably be more appropriately continued by the contractors, since their concepts will be the primary effort in the formal concept formulation phase for ESPAWS. Because of the limited time available, the following tasks were not initiated:

a. Determination of design to unit production costs (DTUPC) and life-cycle costs.

b. Intensive reliability, availability, maintainability (RAM) design and analysis.

c. Acquisition of inputs from outside the Department of the Army.

System Analysis Inputs

Prior to and during concept development, there was a continuous effort to assimilate system analysis results for use as a basis to develop improved battery weapon concepts. The following paragraphs summarize the major considerations that affected concept generation.

A major role of 155mm SPH systems is to meet target servicing requirements requested by the supported maneuver commander in region I. In general, region I translates into an area where targets are at the forward edge of the battle area (FEBA) and up to 10 km beyond it. The primary targets in this region are armored vehicles such as tanks and armored personnel carriers (APC) in arrays of 3, 6, or 10, traveling in columns until they are 1 to 3 km from the FEBA where they shift into fighting formations roughly abreast of each other. While a major role of 155mm systems is to meet these target servicing requirements, they will also be called upon to provide counterbattery fire, interdiction fire, massed fire close to the FEBA, and assorted preparatory fire missions.

Several factors enter into determining the range requirements for 155mm systems. One of these factors is the one-third/two-thirds rule, a doctrine wherein, during offensive operations, the systems are located behind the FEBA one-third the distance of their maximum range. During defensive operations, they are located two-thirds the distance of their maximum range. In addition, while 8-inch SPH and multiple launch rocket systems (MLRS) are normally 5 to 10 km behind the FEBA, doctrine usually shows 155mm SP systems closer to the FEBA.

With respect to minimum range, systems analysis has shown that 155mm systems seldom attack targets at ranges less than 7 to 10 km. Generally, in only 1 to 3 percent of the firing situations is an SPH required to fire at very high quadrant elevations (QE) to distances of 1 to 9 km (e.g., firing over hills).

Recent battlefield surveillance and acquisition materiel advances have increased the number of target acquisitions in region I. This has resulted in significantly more targets than the battalion fire control and weapon systems can adequately service. Recent scenarios have shown that in the high intensity area of a major battle, acquisitions peak at the beginning and may number 100 during the first hour, with 20 to 60 being acquired during each of the remaining hours. Ordinarily, acquisitions during the first hour occur at ranges close to the FEBA. However, because of inadequate response capabilities of current and projected fire control systems and other weapon system limitations, many targets are acquired several times during a battle. As a result, total acquisitions average 175 targets per hour. It should be noted that each of these targets is actually a target array. With full allowance for projected advances in target acquisition, such as the standoff target acquisition system (SOTAS) and battlefield surveillance and target acquisition radar (BSTAR), systems analysis has shown that only 30 percent of the targets in region I are actually acquired. Reaction time for the battalion and batteries is a key factor in meeting target servicing requirements when firing at the fleeting, armored targets in region I. Previous system analyses indicate that for all of the targets forward observers (FO) acquire, they do not relay information on 50 percent of them based on their perception that current artillery weapons cannot react fast enough to engage the additional targets. Analysis efforts on systems such as Copperhead have shown that the number of targets killed decreases significantly as a function of reaction time. (Reaction time is defined as the time span between the call for fire and arrival of the first round). For a 10-target array, the number of targets killed is seriously affected when time delays exceed 150 seconds. At 200 seconds the effectiveness is cut by 50 percent, and at 300 seconds effectiveness is reduced by 90 percent. Part of this degradation is caused by the line-of-sight requirement for Copperhead during semiactive laser terminal homing. However, the effect is there for all contemplated munitions in that longer delays lead to greater errors in predicting the position of targets when the round arrives. In addition, as targets get closer to the FO's, they will relocate because of the increased danger. Though Copperhead requires laser designation during terminal homing, future FO systems may also require a laser range finder similar to the ground laser locator designator (GLLD) in order to accurately obtain information on target positions so that technical fire control computers can calculate predicted target positions and automatically provide information for laying and firing of the weapon. Increased time delays exacerbate the calculation of lead angles and distances. For instance, a column of tanks moving at 15 km per hour will cover 250 meters in one minute. It follows that time delays should be minimized in order to reduce target location errors.

With respect to projectiles, limited studies have shown that, against armored targets, scatterable mines and passive infrared cannon launched guided projectiles (IR CLGP) without line of sight (LOS) restrictions have considerably better kill ratios than Copperhead. However, neither high explosive (HE) nor improved conventional munitions (ICM) rounds (both of which have low target lethality) have much potential against armored targets.

Related systems analysis efforts indicate there are two possible means of increasing survivability. The first approach is to increase our target location error (TLE) when fired upon by enemy artillery. Increasing our TLE from 50 to 150 meters has a major impact on increasing survivability, and if TLE can be increased to more than 300 meters, the weapons are almost invulnerable to fire. There are at least two potential techniques to achieve this kind of improvement. First, the battery may be spread out from its current lazy-W formation and have its fire programmed to confuse counterbattery radar and fire control. Second, is to adopt a "shoot and scoot" firing technique where a weapon moves shortly after firing its first round. Moving within 30 minutes would result in some increase in survivability, and moving within 5 minutes to a position at least 500 meters removed would provide almost complete immunity from counterbattery fire.

Another approach to achieve increased survivablity is to move the battery further to the rear of the FEBA. If the weapons are placed 16 km to the rear, they are out of range of most enemy artillery; if moved back 20 km, they are out of range of over 90 percent of enemy cannon artillery.

## Threat Evaluations

The threat here considered is that of the Warsaw Pact nations whose artillery heavily outnumbers US artillery. While estimates vary, Soviet superiority ratios are thought to be 4 or 5 to 1 and in some cases 7 to 1. In break-thru conditions the ratio may be 13 to 1. The Soviets have also stockpiled large quantities of ammunition for use against targets such as 155mm SPH. Their counterbattery fire radars are excellent and have the potential for speedy acquisition of targets. When considering all of these factors, the principal threat to 155mm SPH is counterbattery fire--and it could be overwhelming. Once our current SPH start to fire, their survivability is questionable. If the Soviets chose to use dedicated counterbattery fire weapons, they can have rounds landing on our SP artillery within 3 to 5 minutes after we fire our first round. Considering their numerical superiority, a dedicated counterbattery fire weapon is a recognizable threat. Direct fire weapons are an additional threat but not a predominant one. The nuclear, biological, chemical (NBC) threat is significant but not quantifiable.

## Potential Payoff Areas

During the study period, a concentrated effort was made to review the previously referenced systems analysis efforts and threat profiles, and to evaluate technology developments to determine what materiel approaches could be ulitized to meet firepower requirements while surviving under battlefield conditions. Following is a summary of potential payoff technology approaches which were considered.

| Materiel Approach | Potential Payoff |
|---|---|
| **Munitions** | |
| a. Antiarmor projectiles such as, scatterable mines, passive infrared cannon launched guided projectiles (IR CLGP), and sense and destroy armor (SADARM). | High potential if fired accurately and responsively against armored moving targets. |
| b. Extended range ammunition. | High potential only with reference to increasing range of antiarmor rounds. Currently, Copperhead has a 16 km range. Extending |

| Materiel Approach | Potential Payoff |
|---|---|
| | range of antiarmor rounds to 22 km is desirable and to 30 or 35 km may be desirable but requires changes in current techniques/doctrine. |
| c. Modular propulsion charges. | High potential to reduce the manpower requirements for handling ammunition and to load the SPH. High potential to increase the firing rate. |
| d. Automatically set fuzes. | High potential to reduce manpower requirements for fuze setting. High potential to decrease the response time. |
| $C^3$/Fire Control | |
| a. Improved target registration procedures and hardware (forward observer prefire for effect (FFE) volley lasing of off-target registration rounds or employment of the artillery registration and adjustment system (ARADS) ). | High potential to significantly reduce the current 250 to 500 meter TLE. |
| b. On-board position location, bearing reference, and technical fire control competition. | High potential for: Increased responsiveness. Improved rates of fire. Quick movement into new firing positions. Increased survivability through the spread battery technique and/or autonomous operations. |
| c. Improved radio and digital data transmission. | High potential to remove bottlenecks in voice and data transmission among the battalion/battery FDC's, the FO, individual weapons, ammunition resupply vehicles, and ammunition trucks going to and coming from ASPs and ATPs. |

| Materiel Approach | Potential Payoff |
|---|---|
| **Ammunition Handling** | |
| a. Improved ammunition resupply vehicle (ARV). | High potential for: Increased basic load of the battery. Modification of ASP/ATP resupply problems under surge battle conditions. |
| b. Automated ammunition handling between the ARV and SPH and within the SPH and ARV. | High potential to: Reduce manpower intensity. Release manpower to other duties. Increase firing rates. Decrease crew fatigue. |
| **Chassis Components** | |
| a. Increase engine horsepower. | Little payoff since 600 hp engines provide adequate hp/ton ratio to meet cross-country mobility requirements. |
| b. On-board auxiliary power unit (APU). | High RAM payoff when used in lieu of the main engine during firing modes. |
| c. Lockout suspension. | High potential to increase weapon response by eliminating requirement for firing spade to absorb recoil shock (hastens getting into and out of firing positions). Simplifies major deflection corrections with tracks as in the Casemate concept. |
| **Miscellaneous** | |
| a. Slide block breech mechanism. | High potential to increase firing rates. Better compatibility with automatic loaders as a means of increasing firing rates. |

| Materiel Approach | Potential Payoff |
|---|---|
| b. M199/M185 cannon interior ballistic configuration. | High potential to be compatible with projectile/propellant charge configurations when firing nominal 100-pound projectiles. Limited growth potential when firing extended range projectiles. (Probably will lead to boosted projectiles with smaller payloads for the extended range application where TLEs are increased). |
| c. NBC protection. | High potential to increase survivability using hybrid design approach. |
| d. Howitzer Test Bed III (HTB III) cannon. | High potential to fire 100-pound spin-stabilized rounds to extended ranges. Potential for higher payloads at ranges from 22 to 40 km as compared to rocket assisted projectiles (RAP) or basebleed projectiles fired from M199/M185 cannon. |

Classes of Concepts

In the early stages of concept generation, certain key facts from previous systems analysis and threat evaluations emerged with overriding emphasis. They were:

a. A major mission of 155mm SPHs is to kill tanks and other moving armored targets in region I.

b. There is a target-rich environment, and current systems are unable to perform their support missions in this environment.

c. Our 155mm systems are, and will always be, vastly outnumbered by Soviet artillery and extremely vulnerable to counterbattery fire once engaged.

The Army has several technology areas in various stages of research and development which could be exploited to generate battery weapon concepts which would meet firing mission objectives and which would survive a battlefield environment. Therefore, in the initial planning stages and during the study, six main classes of concepts evolved, each of which exploited technology in a different manner. The six classes are summarized as follows:

| Class | Primary Mission | Design Approach |
|---|---|---|
| I | Attack region I targets. | Define a baseline system with which other concepts may be compared. Pick and choose the subsystems which will be in the field in the 1982/1983 time frame. Therefore, the assumption is made that the system will consist of subsystems now in the field, will be modified by subsystems now in new production, and will incorporate new subsystems expected to go into production by 1982/1983. |
| II | Attack region I targets. | Develop a weapon system to kill or neutralize targets with scatterable mines; exploit |

| Class | Primary Mission | Design Approach |
|---|---|---|
| | | technology development to increase system responsiveness and survivability thru shoot and scoot tactics. |
| III | Attack region I targets. | Similar to Class II, but employs a passive IR CLGP instead of scatterable mines as the primary target killing mechanism. |
| IV | Attack region I targets. | Use technology to extend range for increased survivability by having the SPH system increase stand off from the FEBA out of range of Soviet cannon artillery. |
| V | Counterbattery fire to augment our 8-inch M110 SPH and MLRS, thus protecting our infantry and armored forces from Soviet cannon artillery fire. | Use technology to extend range for attack of Soviet self-propelled artillery in massed fire and to obtain stand off survivability. |
| VI | Attack region I targets. | Develop a battery weapon system utilizing foreign technology. |

Ammunition Resupply Vechicles

The question of whether an ARV should be used in the battery weapons system was not easily answered, and involved a certain amount of controversy. The following summarizes some of the key issues:

a. Adding another tracked vehicle which does not have a firing capability is costly in terms of acquisition and logistics. The funds might be better spent for additional SPHs.

b. Ammunition handling is a manpower intensive operation. Large numbers of troops are required to manhandle projectiles, break out propellant charges, etc. In addition, with projectiles weighing upwards of 100 pounds, crew fatique becomes a problem. A reduction in manpower requirements would result in reduced salary costs or provide a means for transferring soldiers to other manpower deficient areas.

c. ASPs are a long distance from the battery. ATPs are closer; but still a major problem exists in getting ammunition to the battery. Almost all studies have shown that tremendous quantities of rounds are needed in the first hours and days of high-intensity conflicts, and getting ammunition to the battery is a major bottleneck.

d. Since a major mission of 155mm SPH systems is to attack armored targets, and since antiarmor rounds such as Copperhead are heavier (130 lb vs 100 lb) and longer (65 in. vs 30 in.) than conventional rounds, the ammunition handling probelm is becoming even more difficult.

e. The first hour or hours of a battle are under surge conditions, and the larger the basic load the better, since getting additional rounds up to the battery is very difficult.

Based on all of these factors, it was decided to include an ARV as an integral part of the battery concept. As a result, the ammunition resupply system consists of wheeled trucks traveling in convoy between the ATP/ASP and the battle area where the munitions are transferred to the ARV. The ARV acts as a mobile magazine for the SPH, and can either transfer the rounds to the SPH ready rack or to the storage racks. The ARV can leave the SPH during fire missions and obtain more munitions a safe distance from the highly vulnerable firing area. Another option is to have the ARV positioned next to the SPH and load the rounds directly into the breech during fire missions.

Initially, when evaluating mobility requirements for the ARV, it was decided that it should be tracked for compatibility with the SPH. As the study progressed, discussions were undertaken concerning the potential for a wheeled ARV. While wheeled

ARVs do not have cross-country mobility completely equal to tracked vehicles, they have a significant increase in RAM. In order to obtain a comparison, a limited special study was made at the conclusion of the ASES to develop concepts for a wheeled ARV. In addition, TARADCOM is developing a 8x8 truck having an increased load carrying capacity and greater cross-country mobility. Depending upon the specific battery weapon concepts developed, this truck may have the potential to serve as an ARV.

Engine/Transmission Selection

When selecting an engine and transmission combination for the ASES concepts, the following factors were considered:

a. Power-to-weight ratio.

b. Packaging size.

c. Growth potential.

d. Cost.

e. Logistic and RAM constraints.

It was also decided not to generate a whole series of engine-transmission (power pack) combinations, but to select a "palatable" combination to provide reasonable spatial relationships within the conceptual vehicles. The SPH and ARV wherever possible would share the same engine/transmission combination for logistical reasons. The SPH, because of its weight, dictated the power range of the engine in most cases. For the SPH, a hp/ton value of 17 to 18 was selected to provide the desired mobility. It was also important to select a powerpack which could grow with the vehicle. (As a general rule, a 20 percent growth in vehicle weight is anticipated over the life of the vehicle).

The Cummins VTA-903 diesel in the range of 500 to 600 hp was used for the SPH's and ARV's in all concepts except the SPH in the "C" concepts, which uses the existing Detroit Diesel in slightly modified form and its existing transmission. The VTA-903 also offers power flexibility because it has the potential to grow to 1,000 horsepower. The weight and overall dimensions of the engine are not excessive.

The AMX-1000 transmission was selected for use in most of the concepts because it represents an extension of proven technology, is a big improvement over existing transmissions, and offers simple engine/transmission/vehicle control interfaces. Powerpack heat build up has been a problem in many tracked military vehicles, but the AMX-1000 reduces this because of its increased efficiency. It is more efficient because it has six speeds with automatic lock-up and because of a decreased reliance on the torque converter for torque multiplication.

Also considered but not used were the gas turbines currently being developed for long life operation in heavy-duty trucks. These engines are becoming competitive with diesels with regard to fuel consumption and cost. They offer the potential of high power to weight, reduced maintenance, and require a short warmup time.

Concept Development Team

While the final concepts were generated by the Large Caliber Weapon Systems Laboratory, numerous inputs were obtained from other Army organizations. Following is a listing of those organizations with summaries of their contributions:

| | |
|---|---|
| Ballistics Research Laboratory | Vulnerability analysis of SPHs and ARVs. Concept design information for ammunition compartment. |
| Chemical Systems Laboratory | NBC protection design and materiel approachs for crew members; compartment overpressure design approachs, and detection and decontamination. |
| TARADCOM | Design inputs and performance characteristics of engines, transmissions, and other automotive components. Data inputs used to develop concepts for wheeled ARVs. |
| MERADCOM | Design parameters/constraints for ammunition pallets to assure or evaluate compatibility with the logistics tail from the load, assemble, and pack (LAP) plant to the ASP/ATP. |
| Human Engineering Laboratory | Human Engineering Laboratory battalion artillery test (HELBAT) information; ammunition handling procedures at the ASP/ATP; ARV/SPH ammunition handling characteristics and demonstrations; results of recent tests and analysis on battery emplacement times and procedures. |

| | |
|---|---|
| Fire Control and Small Caliber Weapon Systems Laboratory | Concepts for the battery and battalion FDC module and integration/installation on a tracked vehicle. On-carriage automated fire control system. |
| CORADCOM | Program and technical information concerning voice and data transmission developments. |

Class I (Baseline System - M109A2 SPH)

Concept Development Philosophy

The objective for the Class I concept was to develop a baseline battery weapon system which would portray the 155mm battery as currently envisioned for the early- or mid-1980 time frame. It would consist of the following types of materiel:

a. Currently fielded equipment which is expected to continue to be fielded.

b. Equipment which is in new production.

c. Equipment which is expected to complete development at an early date and enter into new production.

This approach establishes a baseline of what SPH capability would be without the ESPAWS program and, therefore, provides a bench mark for comparison with the new systems.

M109A2 Self-Propelled Howitzer

General

The M109A2 SPH battery is composed of two 4-howitzer platoons. Each platoon is equipped with an M577A1 armored, tracked, command post containing a battery computer system (BCS) fire control. The howitzers are nominally deployed in a terrain gun emplacement formation 40 to 70 meters apart with an M548 ARV assigned to each howitzer and serving as a mobile ammunition magazine.

The howitzer, shown in figure 1, is a full-tracked, armored, air-transportable, diesel-powered vehicle which carries 36 rounds including 22 long wheelbase rounds in the turrent bustle and two XM712 Copperhead rounds inside the crew compartment. The primary armament is an M185 155mm cannon having an M178 mount. The howitzer is capable of firing conventional, selected, and nuclear ammunition at a maximum rate of four rounds per minute dependent upon the type of projectile being fired. The M109A2 is assumed to have whatever changes are required to make it compatible with the M203 propellant charge to fire the M549 RAP and achieve a maximum range of 30 km.

The family of 155mm munitions consists of projectiles, bagged propellants, fuzes, and a primer. Primary types of rounds include the M107 HE, the M483 ICM, the XM712 Copperhead, and the M549 RAP-HE plus smoke and incendiary. The M203 propellant charge is approximately 30 inches long and is the charge required to obtain a 24 km range for the unboosted M549. A separate assembly of propellant charges is

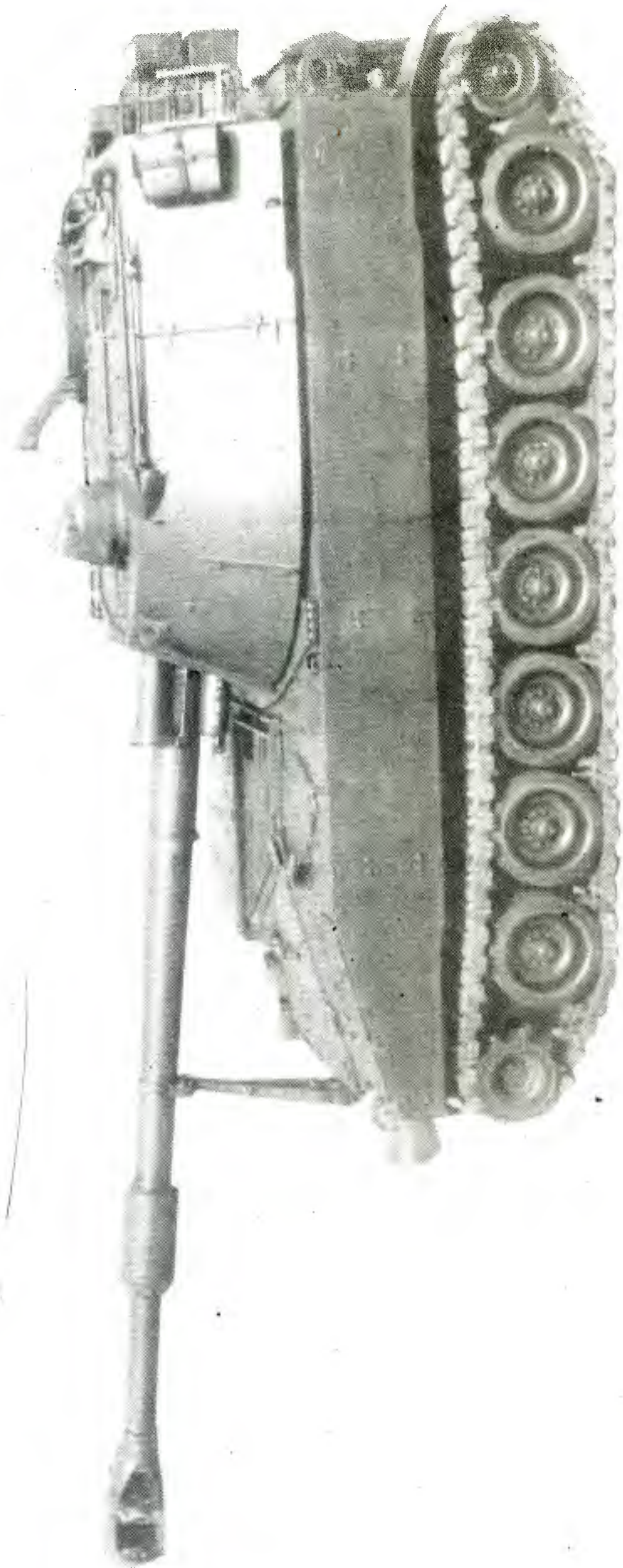


Figure 1 M109A2 Self-Propelled Howitzer

provided to obtain the required zoning for short and intermediate ranges. Fuzing options include point detonating, mechanical time/super quick, proximity, and mechanical time. The primer is a percussion type consisting of black powder with an igniter. The SPH is powered by a 405-hp diesel engine and driven by a torque converter transmission. Electrical power is supplied by four 12-volt batteries. The suspension system is made up of torsion bars extending across the bottom of the chassis and does not have a lockout feature. Located on the rear of the chassis are two firing spades used to transmit recoil loads into the ground.

The physical and performance characteristics of the baseline concept are summarized in tables 1 and 2, respectively.

### Turret/Armament

The turret is capable of traversing 6,400 mils and has 1-1/4 inches of armor on its top and sides. The weapon can be fired from -53 to 1,333 mils in elevation. A bore evacuator provides for elimination of propellant gases. Hydraulic powered controls are used to elevate the gun mount and traverse the turret.

### Ammunition Handling

Normally, the ammunition is transferred from the ARV through the rear chassis doors into the crew compartment. The projectiles are manually lifted onto the semi-automatic hydraulic-powered rammer and rammed into the cannon. Following manual loading of the bagged charges, the screw-type breech mechanism is closed, the weapon is primed, traversed, elevated to the required position, and fired. The initial firing rate is restricted to four rounds per minute for three minutes (cannon temperature limitation). The sustained firing rate is two rounds per minute. In an alternative procedure, the rounds from the turret bustle may be manually loaded on the rammer and then rammed and fired. Fuzing is accomplished manually, either before or after the projectiles are brought into the howitzer.

### Fire Control and Communication Equipment

The 8-gun battery is split into two 4-gun platoons, each of which has an M577A1 command post (figure 2) located within 200 meters of the weapons. While wire was previously laid between the command post and the howitzers to relay data from the technical fire control computer, it is assumed that transceivers now being developed will be incorporated into the baseline battery to eliminate the need to lay wire.

Table 1

Baseline System - Physical Characteristics

| | |
|---|---|
| **General Data** | |
| SPH combat loaded weight (lb) | 55,000 |
| SPH dimensions - length (in) | 243 |
| - width (in) | 123 |
| - height (in) | 129 |
| Crew size - SPH | 6 |
| - ARV | 4 |
| - Command post | 7 |
| **Firepower** | |
| M185 cannon | |
| Number of rounds carried - SPH | 36 |
| - ARV | 88 |
| Family of projectiles | HE, ICM, Cooperhead |
| Type of ammo handling | Manual load, automatic ram |
| **Mobility** | |
| Engine | Detroit Diesel 8V71T 405 hp |
| Transmission | Torque converter XTG-411-2A |
| Lockout suspension | None |
| **Survivability** | |
| SPH armor protection | Aluminum |
| NBC protection - SPH | None |
| - ARV | None |

Table 2

Baseline System - Performance Characteristics

| | |
|---|---|
| **Firepower** | |
| Min/max range (km) | |
| ICM | 3-22 |
| HE (RAP) | 3-24 (30) |
| Copperhead | 3-16 (18 FUFO) |
| Responsiveness | |
| SPH firing rate | |
| Burst | 12 rds/3 min |
| Sustained | 2 rds/min |
| Copperhead | 1 rd/min |
| Relocation time | |
| Deliberate move (min) | 60 |
| Survival move (min) | 42 |
| **SPH Mobility** | |
| Cruising range (mi) | 217 |
| Hp/ton | 14 |
| Max speed (mph) | 35 |
| **Ammunition Supply** | |
| Basic load 8 SPH/8 ARV/5 trucks (rds) | 1,392 |
| Battery resupply rate (17 trucks at battalion) | |
| 40% ASP/60% ATP (rds/day) | 3,800 |
| 100% ATP (rds/day) | 6,800 |

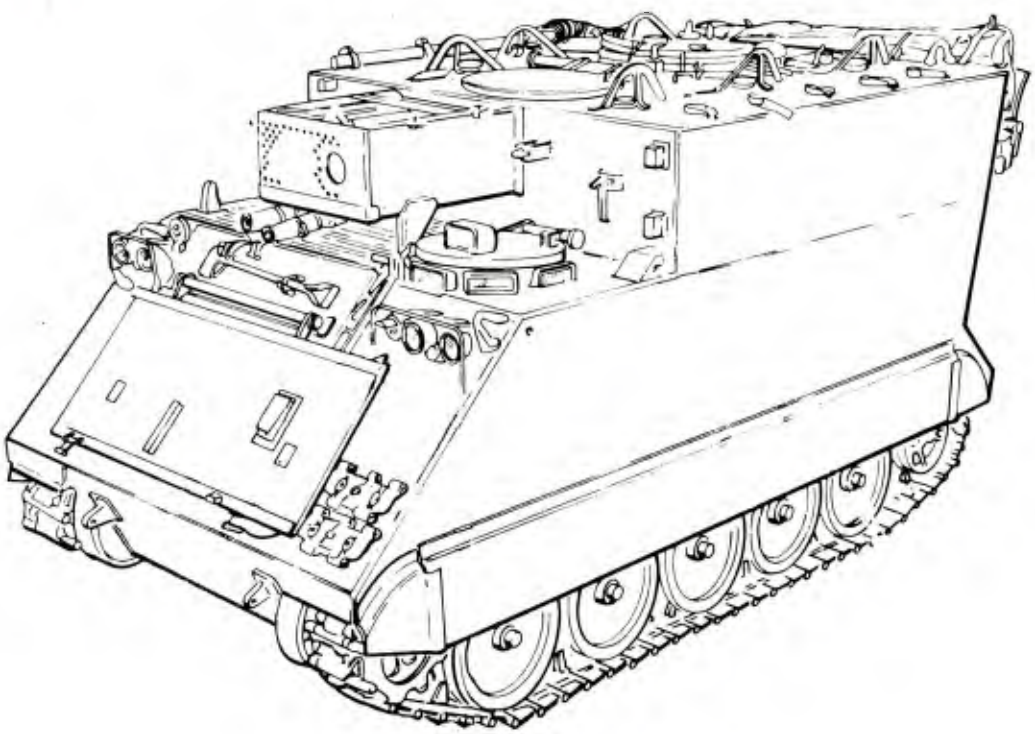


Figure 2 M577A1 Command Post

Twenty minutes is required to move into a previously layed out firing position. Following a firing mission, approximately 10 minutes is required to displace the battery. Batteries make two kinds of moves. A deliberate move is a preplanned move, and is based on expected relocation of the FEBA. This move takes approximately 60 minutes, and consists of a 10-minute displacement time, a 30-minute travel time, and a 20-minute emplacement time. A survivability move is an emergency move caused by counterbattery fire and nominally requires 42 minutes which consists of a 10-minute displacement time, a 12-minute travel time, and a 20-minute emplacement time.

Target acquisition capability is provided by fire support teams (FIST). The FIST consists of nine FO in three-man units using field glasses for target acquisition. The FIST team leader has a FIST vehicle equipped with a ground/vehicle laser locator designator (G/VLLD) and a digital message device (DMD) for target data transmission. The G/VLLD (figure 3) sends the following types of data to the battalion FDC or platoon command post:

a. FO range to target.

b. Azimuth of the target with respect to the FO.

c. Elevation angle of the target with respect to the FO.

Based on this data, the BCS, located in the M577A1 command post, calculates the position of the target with respect to the FO. The DMD (figure 4) transmits and receives digital firing data.

### NBC Protection

None of the equipment in a 155mm battery has NBC protection.

### Crew Requirements/Functions

Following are listed the crew members for the M109A2:

Driver - Operates and maintains the vehicle and assists in ammunition handling.

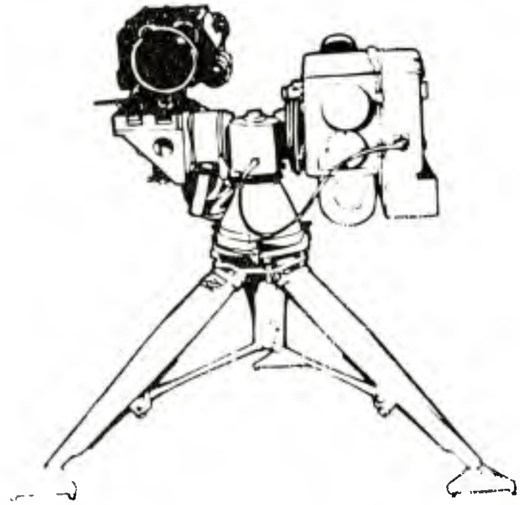


Figure 3 Ground/Vehicle Laser Locator Designator (G/VLLD)

Figure 4 Digital Message Device (DMD)

Chief of section - In charge of communication, coordination, etc.

Gunner - Operates fire control equipment.

Assistant gunner - Operates fire control equipment.

Cannoneer (2) - Handle and load munitions.

The following personnel are required to operate the M577A1 command post:

Fire direction officer (FDO).

Fire direction computer operator (2).

Fire direction specialist (4).

Following are listed the crew members for each M548 ARV:

Driver - Operates and maintains vehicle and assists in ammunition handling.

Ammunition handlers (3) - Handle and fuze projectiles; set and handle propellant charges.

Ammunition Resupply Vehicle (ARV)

The M548 (figure 5) carries 88 complete rounds. This vehicle is either backed up to the M109A2 or is positioned close to it so that munitions can be manhandled from the M548 into the M109A2.

Resupply Trucks

M813 5-ton resupply trucks (figure 6) transport munitions from the ASP or the ATP to the battery. These unarmored trucks have a 100-percent overload capability and also pull 1-1/2 ton trailers for a total maximum payload of 11-1/2 tons. However, when these overloads are carried the RAM decreases considerably and vehicle speeds and cross-country mobility are drastically reduced. As a result, for the baseline concept, it was assumed that 100 rounds would nominally be carried. In order to transfer the ammunition, the M813 trucks are backed up to the M548s where the required number of projectiles are depalletized (by removing the securing bands) and are dumped on the ground. The projectiles are then picked up by hand and stowed in the wooden pallets (less the bands) in the M548 until they are required by the SPH.

Figure 5 M548 Ammunition Resupply Vehicle

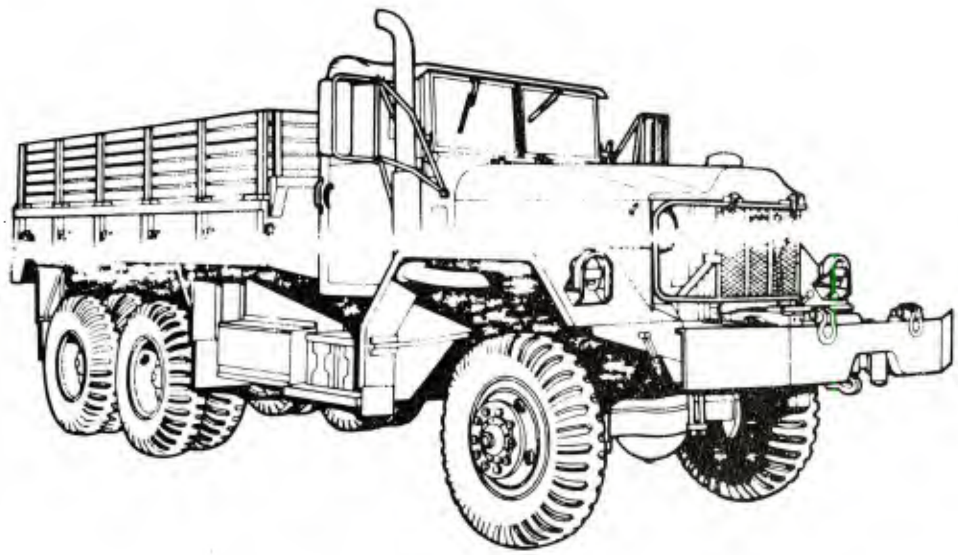


Figure 6 M813 5-Ton Truck

The fuzed projectiles and propellant charges are then transferred manually into the M109A2.

Class II (Shoot Scatterable Mines and Scoot)

Concept Development Philosophy

Class II concepts were synthesized to meet the following main objectives:

a. Defeat moving armored targets in region I[1].

b. Survive the counterbattery fire threat.

c. Provide ammunition on a timely basis.

In order to attain these objectives, a common philosophy was used for the three concepts developed in this class.

First, in order to defeat the targets it was decided to fire an "area type" round, accurately and with little time delay, in and around the target complex. Since a major mission of a 155mm SP battery weapon system is target servicing, this lead to the selection of scatterable mines as the high-density round providing the antiarmor firepower. Also, since a large number of targets are identified in a short period of time, each battery concept was required to have the following firepower characteristics:

a. Fire a burst of 18 rounds at the highest practicable firing rate.

b. Reduce the TLE to 85 meters.

c. Provide a fast response capability so that rounds could be fired immediately after the FO identifies and locates the target.

---

[1]While the Class II concepts were optimized to defeat armored targets, an ability was retained to provide massed fire in the traditional cannon artillery role.

Second, in order to survive, it was decided to use the "shoot and scoot" mode of operation. This led to development of concepts which have a capability to quickly move out of firing positions and into new firing positions with time delays much shorter than current systems.

Third, in order to significantly improve ammunition resupply, it was decided that each SPH should have a tracked companion vehicle which would periodically meet the howitzer to resupply its load of ammunition.

Fourth, each of the concepts would use material handling equipment to speed the transfer of ammunition and to reduce the workload on the crews.

Given the aforementioned guidelines, the following battery concepts were developed:

a. Concept IIA consists of a casemate SPH, a companion ARV, and a battery fire control vehicle integrated with FIST.

b. Concept IIB consists of an all-new turreted SPH, a companion ARV, and a battery fire control vehicle integrated with FIST.

c. Concept IIC consists of a maximum product-improved M109 SPH, a companion ARV, and a battery fire control vehicle integrated with FIST.

Casemate SPH (Concept IIA)

General

This concept employs an armored casemate (turretless) self-propelled vehicle (figs. 7 and 8). Armor protection similar to that of the current M109 is provided by 1-1/4 inches on the top and sides and 1/2-inch on the bottom of the vehicle. The candidate power package consists of a Cummins VTA-903 550 hp engine employing an AMX-1000, 6-speed hydrokinetic transmission with bias path hydrostatic steering. This combination with a 318 gallon fuel tank provides for a cruising range of 500 kilometers and a top speed of 61 km/hr. Engine cooling is accomplished by an 8,500 cubic inch radiator with twin 18-inch diameter fans. Four 12-volt batteries supply the electric power required when the main engine and a 25 hp APU are not running. The APU is used to drive the hydraulic power units and charge the electrical system when the main engine is not operating.

The vehicle, weighing approximately 67,000 pounds, has 8 pair of road wheels with trailing arm suspension and full width torsion bars with hydraulic damping. A wheel lockout system stabilizes the vehicle during firing thus obviating the need for spades. In order to facilitate the ammunition resupply operation, a power elevating platform is provided. This platform adjusts to various heights to align a specially designed pallet to the ready rack during the resupply cycle.

A casemate vehicle was chosen because the following advantages are realized:

a. Large ammunition capacity.

b. Fully automatic, high rate of fire loader.

c. Rapid rate of resupply without excessive manpower requirements.

d. Ease of providing NBC protection.

The physical and performance characteristics of this concept are summarized in tables 3 and 4, respectively.

Armament

The main armament consist of a 155mm cannon which is similar to the M199, but with an inverted slide block breech and bore evacuator. It is mounted in a compressible fluid recoil mechanism system. The recoil stroke is 20 inches long with a cycle time of 500 miliseconds. Gun laying is accomplished by using the vehicle tracks for major deflections and a double eccentric trunnion cam mechanism (figure 9)

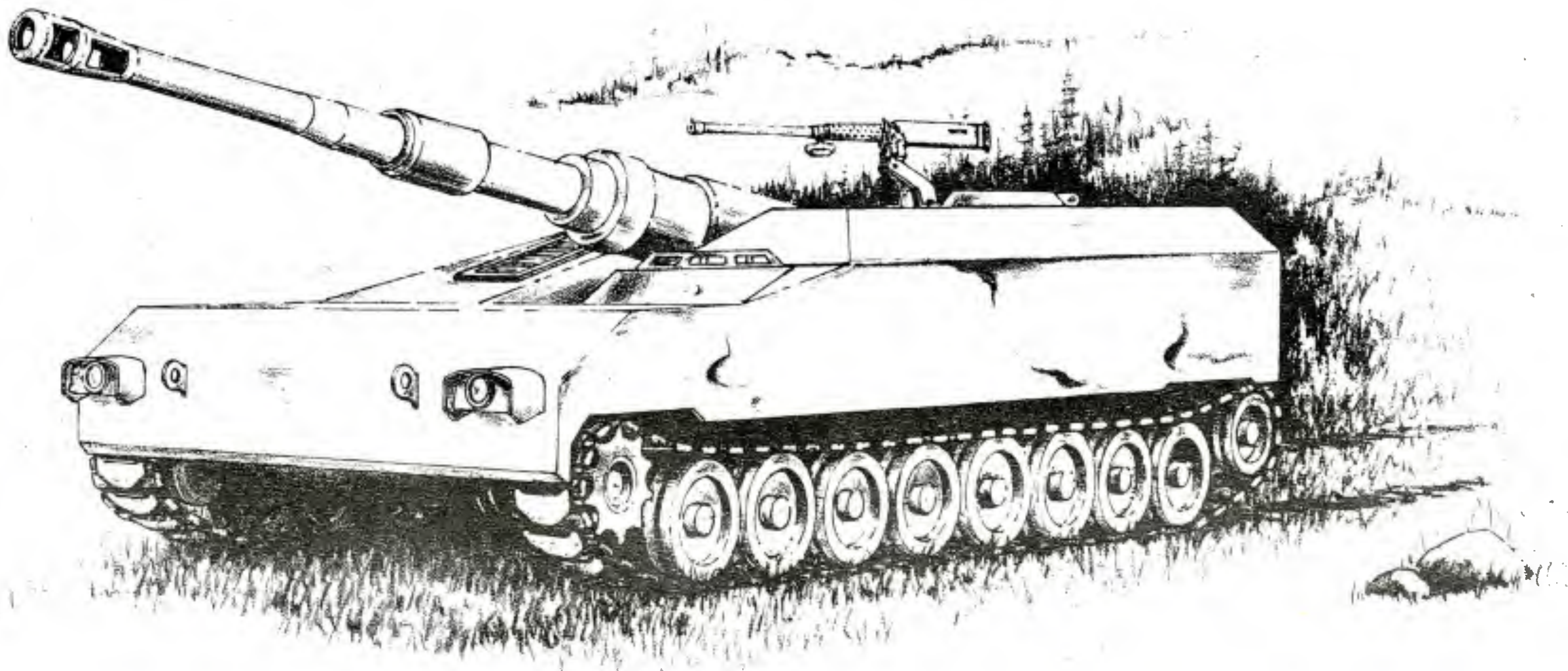


Figure 7 Casemate SPH-Perspective View (Concept IIA)

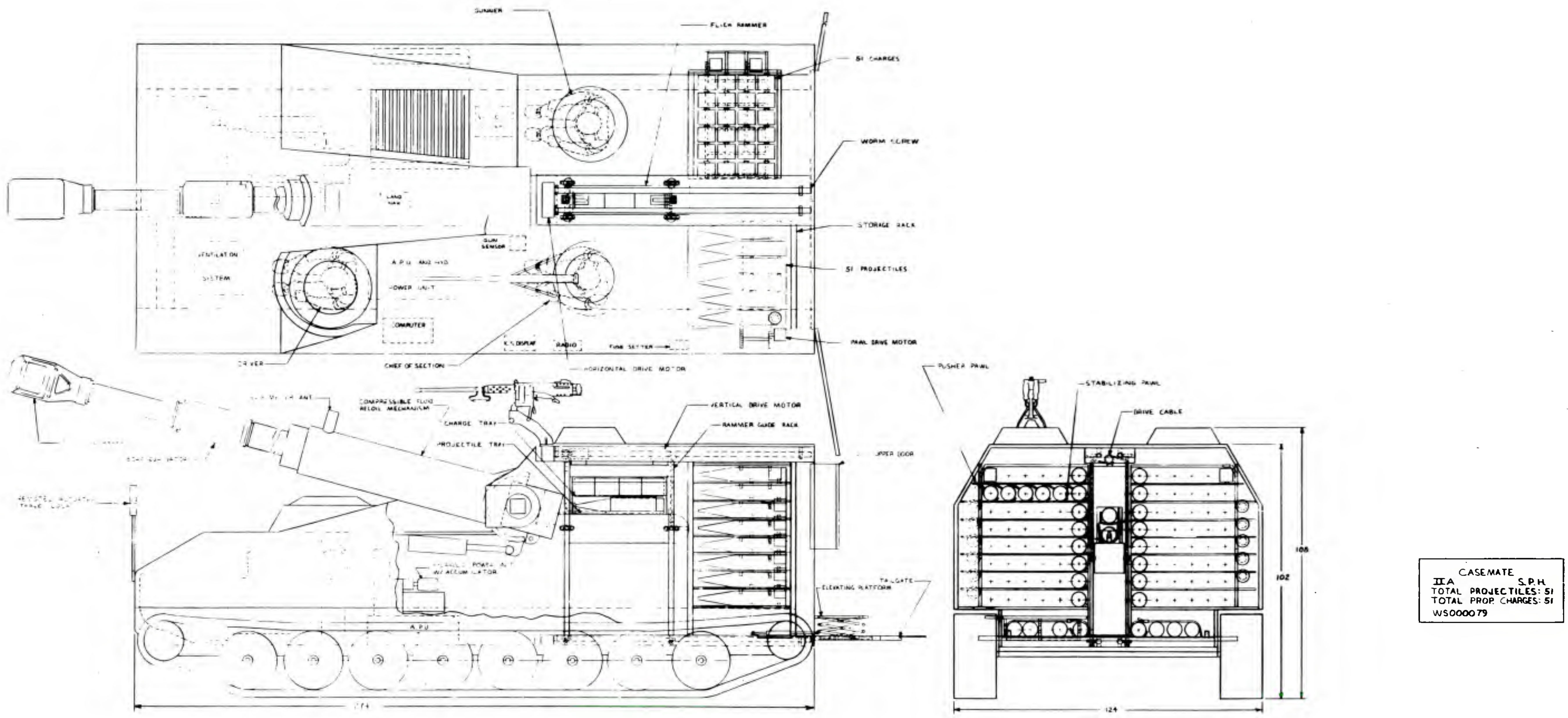



Figure 8 Casemate SPH - Outline View (Concept IIA)

Table 3

Casemate Concept IIA - Physical Characteristics

| General Data | SPH | ARV | Ammo Truck |
|---|---|---|---|
| Weight | | | |
| Combat loaded (lb) | 67,000 | 58,000 | 51,000 |
| Net weight (lb) | 55,900 | 29,000 | 27,800 |
| Fuel capacity (gal) | 318 | 318 | 100 |
| Personnel | 3 | 3 | 2 |
| Dimensions | | | |
| Length (in) | 274 | 274 | 349 |
| Width (in) | 124 | 124 | 96 |
| Height (in) | 108.5 | 98 (gantry depressed) | 108 |
| Ground clearance (in) | 17 | 17 | 17 |
| Wheel size (in) | 24 | 24 | 24X20.5R |
| Track width (in) | 16 | 16 | - |
| **Firepower** | | | |
| Armament | 155mm cannon, .50-cal mg | .50-cal mg | - |
| Elevation/depression (deg) | +75/0 | - | - |
| On-board traverse (deg) | ±5 | - | - |
| Breech type | Slide block | - | - |
| Number of rounds carried | 51 | - | - |
| Family of projectiles | Scatterable mine/ICM/HE | Scatterable mine/ICM/HE | Scatterable mine/ICM/HE |
| Type of ammo handling | Auto load/auto ram | Power assisted (gantry) | Crane |

Table 3

Casemate Concept IIA - Physical Characteristics (Cont'd)

| | SPH | ARV | Ammo Truck |
|---|---|---|---|
| **Mobility** | | | |
| Suspension | Full width torsion bar | Full width torsion bar | Walking beam |
| Lockout on suspension | Yes | No | No |
| Automotive | | | |
| Engine | Cummins VTA 903 | Cummins VTA 903 | 440 diesel |
| Transmission | AMX 1000 | AMX 1000 | Hydrokinetic automatic |
| **Survivability** | | | |
| Armor protection (in.) | Aluminum 1.25 (same as M109) | Aluminum 1.25 (cab only) | - |
| NBC protection | Hybrid-(ventilated face-piece) (positive pressure) | Hybrid-(ventilated face-piece) (positive pressure) | Ventilated facepiece |

Table 4

Casemate Concept IIA - Performance Characteristics

| Firepower | SPH | ARV | Ammo Truck | Battery |
|---|---|---|---|---|
| Min/max range (km) | | - | - | - |
| Scatterable mine | 8/22 | - | - | - |
| ICM (RAP) | 8/22 (30) | - | - | - |
| HE (RAP) | 8/22 (30) | - | - | - |
| Shoot and scoot response | | | | |
| Firing rate | 18rd/1.6 min | - | - | - |
| .5 to 2 km relocation time (min) | 15 | - | - | - |
| Max weapon missions/hour | 3 | - | - | - |
| TLE (m) | 85 | - | - | - |
| Battery ammunition usage (rds/day) | | | | |
| 17 target/hour | 7,344 | | | |
| Max firing rate | 10,368 | | | |
| **Ammunition Supply** | | | | |
| Ammunition resupply (min) | 10.7 | 17.5 | | |
| Basic load (rds) | 51X8 = 408 + | 144X8 = 1152 + | 120X6 = 720 = | 2,280 |
| Battery resupply rate (17 trucks at battalion) | | | | |
| 40% ASP/60% ATP (rds/day) | | | | 4,640 |
| 100% ATP (rds/day) | | | | 8,160 |
| **Mobility** | | | | |
| Cruising range (km) | 500 | 500 | 600 | |
| Hp/ton | 16.4 | 18.9 | 17.3 | |
| Max speed-primary roads (kph) | 61 | 61 | 89 | |
| Ground pressure (psi) | 11.5 | 11 | - | |
| Max grade (%) | 60 | 60 | 60 | |
| Verticle obstacle (m) | 0.5 | 0.5 | 0.4 | |

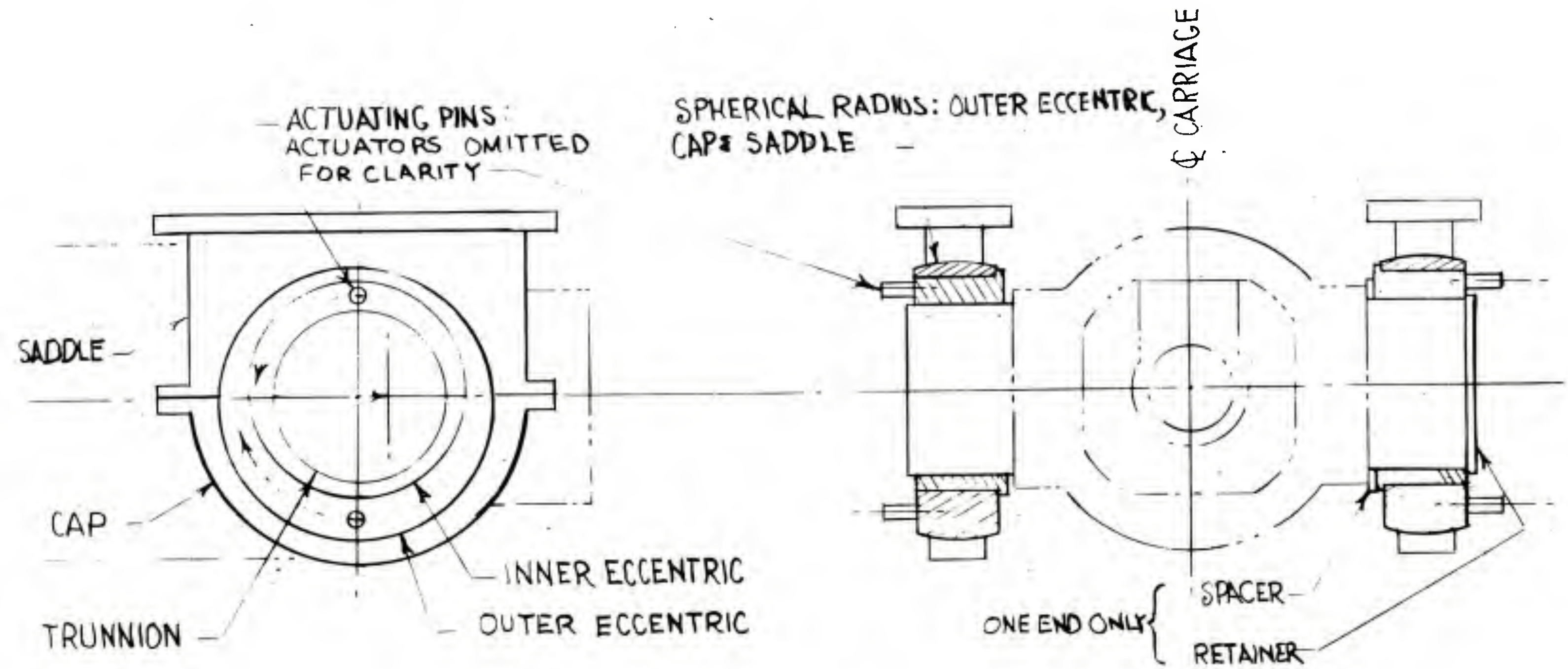



Figure 9 Casemate Traverse Adjuster (Concept IIA)

to achieve final adjustment. The tracks can be driven by the main engine, or by the APU (hydrostatically), or by mechanical inputs into the transmission. Use of the eccentric trunnions will permit up to $\pm 5$ degrees azimuth adjustment. The secondary armament consists of a .50-caliber pintle-mounted machinegun.

The scatterable mine projectile will weigh between 100 and 125 pounds and will be 35 to 40 inches long. The shape will be similar to the M483 projectile. The propellant charge will consist of four, rigid, identical increments, each 6 inches in diameter, 7-1/2 inches long, and weighing approximately 6-1/2 pounds. Since the increments are identical, there is no specific base charge, thus simplifying the loading operation. All the increments are compatible and may be matched with any other increment without adversely affecting the performance. As a result, the increments are shipped in boxes (figure 10) rather than pallets of full charges. This will facilitate shipping by maximizing density of packing. There are three zones of this M31 stick propellant with the low zone having two increments. A 2-increment charge was dictated by the probability that the low pressure generated by a single increment would cause a round to stick in the chamber. The ballistic ranges are 8,000 to 13,500 meters at charge 1 (2 increments), 11,200 to 17,900 meters at charge 2 (3 increments), and 14,100 to 22,000 meters at charge 3 (4 increments). Therefore, the overlap for charges 2 and 3 are 21-and 26-percent, respectively.

Automated Loading System

The autoloader incorporates a flick rammer and double tray for handling the projectile and propellant charge as a single unit. The flick rammer and trays are located at the center of the ammunition ready rack and move vertically as well as horizontally from the gun chamber to the rear of the cab between the storage racks. During firing and when the vehicle is traveling, the flick rammer and trays are stored between the projectile and charge sections of the ammunition rack.

When a fire command is received by the on-board computer, the trays are automatically transported to the proper vertical position to receive the projectile and the charge via an electric drive system. Both the charge and projectile are simultaneously loaded into their respective trays from opposite sides of the vehicle. See figure 11 for an operational view of the autoloader. With the charge in the upper tray, the tray loading sequence is as follows:

1. When the rammer/tray unit is properly positioned, the sides of the trays nearest the projectile and charge to be loaded are lowered and a switch is activated to disengage the projectile/charge stabilizing pawls. This switch also starts the electric horizontal pawl drive motor which drives pusher pawls and indexes the projectile/charges in a transverse horizontal direction one projectile/charge diameter toward the center of the vehicle. This action causes the center-most

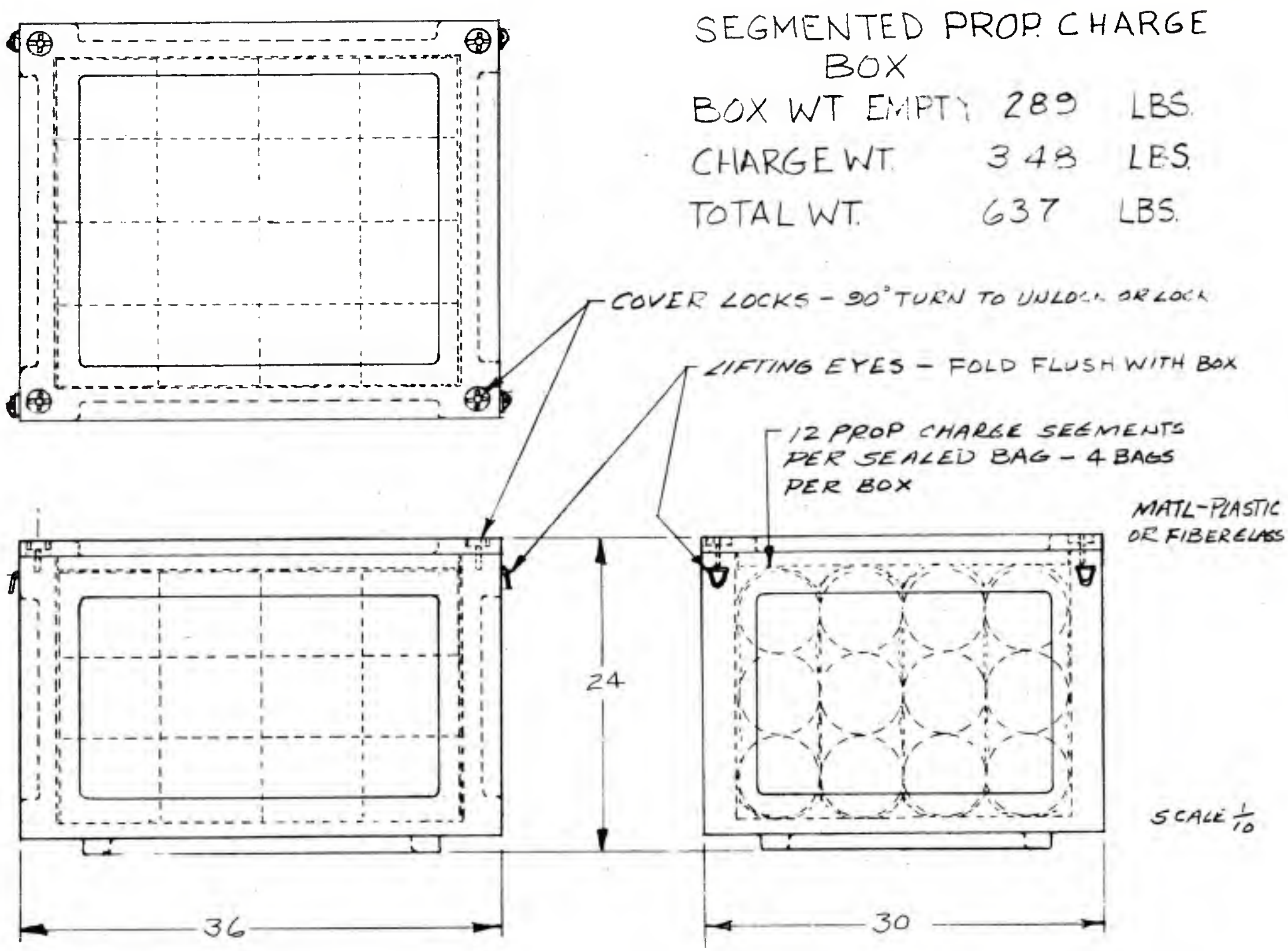



Figure 10 Propellant Charge Box (Concept IIA)

projectile to move into its respective tray. The charges are placed into the upper tray and the projectiles are placed into the lower tray of the unit. Upon completion of this indexing operation, the motor reverses to engage the stabilizer pawls and return the mechanism to its original position. The fire control computer selects and activates from two to four of the charge pawl systems to place the increments for the desired zone into the upper tray.

2. After the projectile and charges are in the trays, two motor-driven worm gears move the loader forward to the breech. The loader operates within a zero to 30-degree range of gun elevation. If the desired firing elevation is greater than 30 degrees, the tube must be depressed to 30 degrees, loaded, and returned to the desired elevation. After the projectile is flick-rammed into the chamber, the bottom of the charge tray opens permitting the charge to drop into the bottom tray. The flick rammer then loads (at a much slower velocity) the charge. After loading the charge, the rammer returns to a stowed position in order to clear a path for the recoiling gun components.

3. The upper-most tier of projectiles must be manually loaded or readjusted since the loading mechanism cannot, due to physical constraints, move to that height.

4. Resupply of the ready rack is accomplished from the rear. The projectiles are placed in the ready rack by using the pallet depicted in figure 12 as a loading fixture. All charge increments are hand loaded. Upon firing, the projectile velocity is measured by a velocimeter and the data is fed into the on-board fire control computer which determines the desired fuze setting. The fuze, which is energized by a magnetic setback generator, now receives its correct setting via a radio frequency (RF) signal initiated by the computer.

Fire Control and Communication Equipment

The heart of the on-carriage fire control system is the ballistic computer. It receives weapons location data from a land navigation subsystem, gun pitch, roll, and direction from gun sensors, meterological data from MET MESSAGE, propellant charge temperature from the propellant charge monitor, and the fire mission from the battery FDC. Through a digital message device, the computer activates the automated loading system for selection of propellant charge and desired projectile from the ready rack. After the gun has been loaded and automatically laid to the calculated azimuth and elevation, the chief of section display indicates the actual weapon settings compared to the specific fire commands. The computer will disable the weapon unless proper

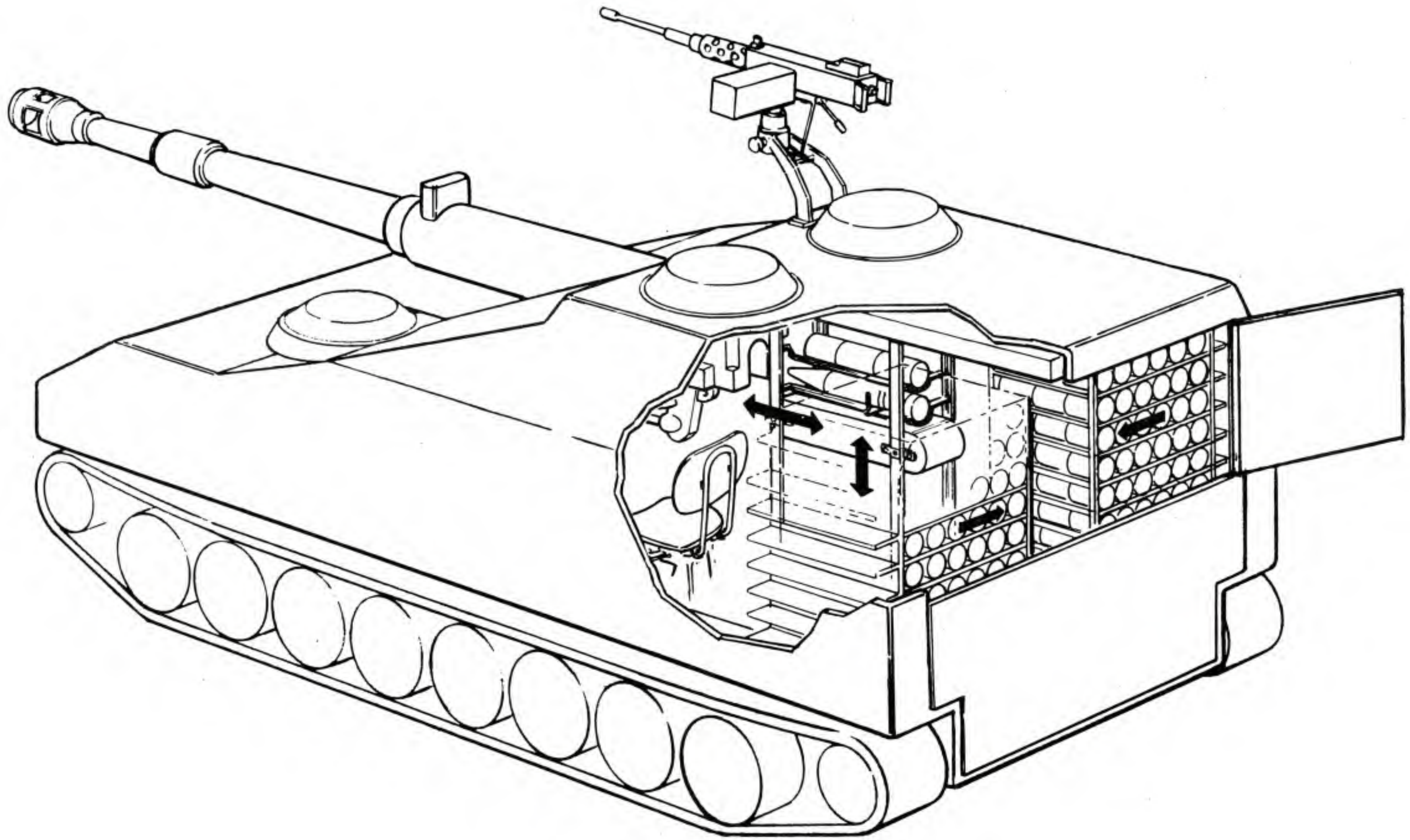


Figure 11 Operational View of Autoloader (Concept IIA)

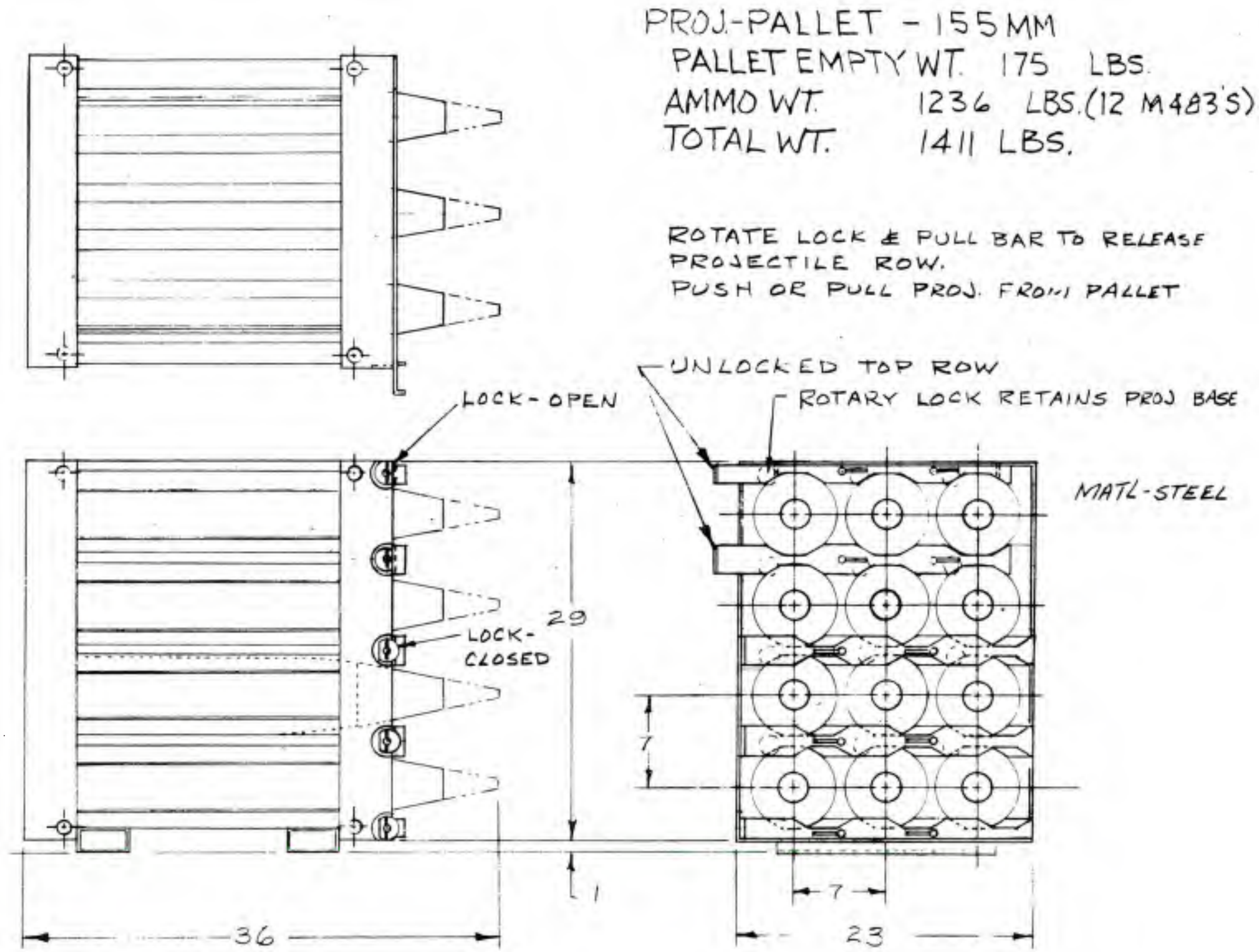



Figure 12 Projectile Pallet (Concept IIA)

verification is made. Location of the fire control computer, velocimeter, land navigation system, gun sensor, fuze setter, radio, chief of section display, and power package are shown in the SPH layout (figure 8).

NBC Protection

A ventilated facepiece is employed. A positive pressure system is also utilized. Using a hybrid system, the SPH can fire 51 rounds; 42 rounds can be fired automatically from the ready rack and 9 can be fired manually before it becomes necessary to resupply. Resupply would take place in a prearranged "clean" area an appropriate distance from any contaminated area.

SPH Crew Requirements/Functions:

Driver - Operates and maintains vehicle. Also assists with ammunition handling.

Chief of section - Responsible for communication and cordination of activities. Also uses .50-caliber machinegun.

Gunner - Operates fire control equipment and handles ammunition.

Ammunition Resupply Vehicle (ARV)

The basic chasis of the resupply vehicle is identical to the SPH to achieve matching performance, maximum commonality of parts, and minimum cost. To provide the largest resupply payload, only the cab has armor protection. The maximum load is 144 complete rounds. The ammunition is transferred to the SPH by means of a gantry crane mounted on four boot-protected vertical screw jacks. (The screw jacks are required to reduce the gantry height during transportation through railroad tunnels conforming to the STANAG configuration.) The projectiles face outward to permit the fuzes to be installed from fold-down platforms mounted on the sides of the ARV. Fuzes and miscellaneous storage space is available under the cargo bed between the sponsons. The ARV is shown in (figure 13). It should be noted that elimination of the gantry crane would permit a maximum load of 216 projectiles and propellant charges. However, the loading time would be significantly increased.

The projectiles are fuzed and made ready for transfer to the SPH prior to initiation of the loading sequence. The ARV is "docked" in a back-to-back fashion and the SPH power tailgate is opened. The ARV gantry lifts a 12-projectile pallet onto the SPH tailgate platform using the guides on the platform to properly position the pallet. The pallet design utilizes projectile center spacing which matches that of the weapon stowage matrix. Alignment of the horizontal projectile and stowage matrix centerlines is accomplished by means of a power platform which is programed to stop

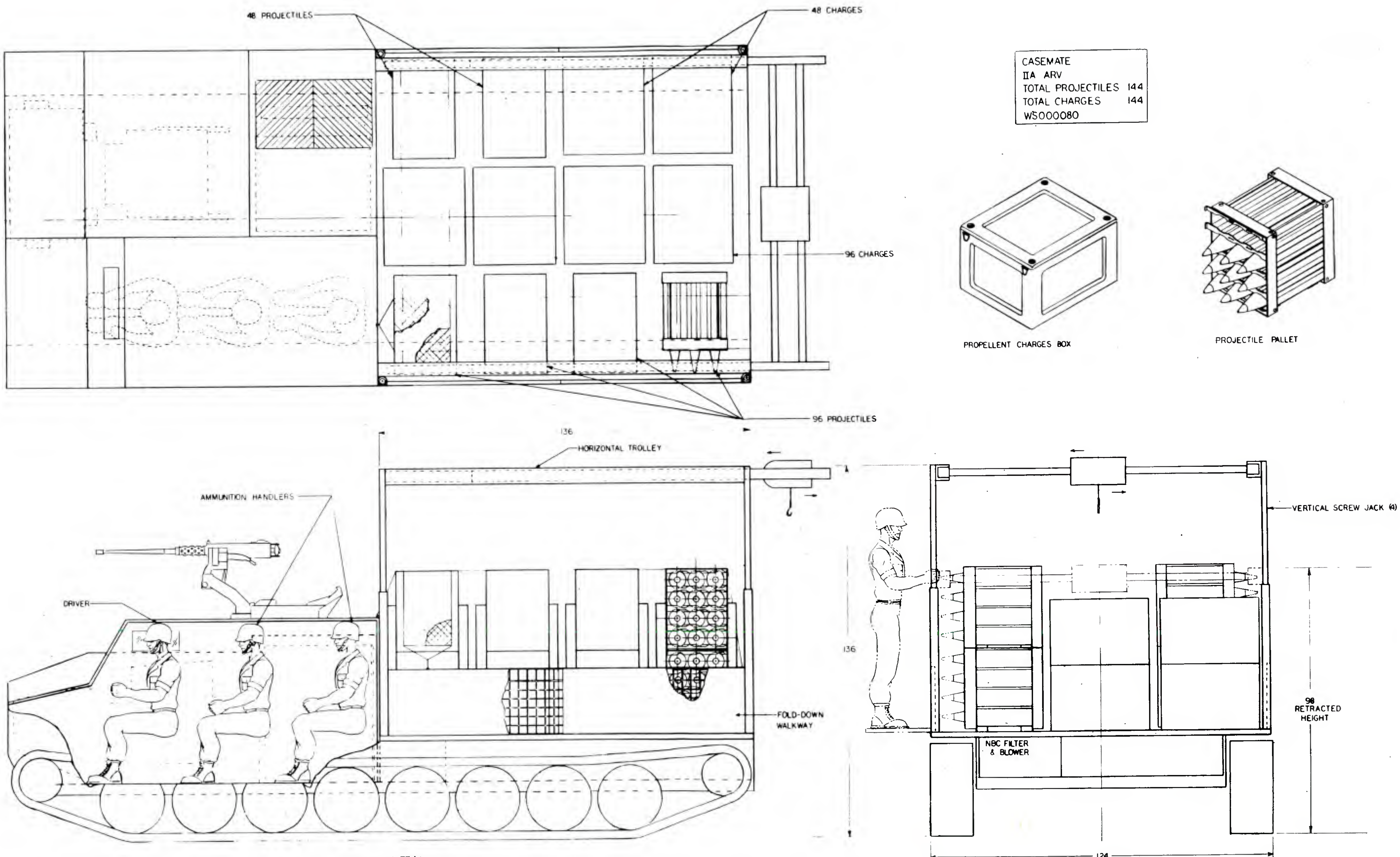



Figure 13 Casemate ARV (Concept IIA)

at either of two selected heights. The projectiles are then push-loaded into the ready rack. The pallet is discarded and the process is repeated until the ready rack is full. See (figure 14) for a view of the transfer of ammunition. A total of 47 projectiles can be stowed in the ready rack. Four additional projectiles may be stored under the rack. Upon completion of the projectile loading sequence, two boxes of propellant charges (24 complete charges of 4 increments) are placed on the tailgate. To save time, the boxes and the individual 3-round vapor barrier bags are opened on the ARV and are subsequently discarded. The most efficient way to resupply the charges is manually, since the ready rack may contain residual increments not fired in the preceding missions. A time study for resupplying the SPH from the ARV is shown in table 5.

Resupply Truck

The ammunition supply truck (figure 15) is an articulated 8x8 vehicle capable of carrying 120 projectiles with their fuzes and propellant charges. The procedure for resupplying the ARV from the truck is shown in (figure 16) and consists of the following steps:

1. Drive the truck behind the ARV to form a T-configuration.
2. Extend the ARV gantry over the truck bed to pick up pallet (gantry can be extended to center of truck bed).
3. Transfer pallet from truck to ARV.
4. Repeat process until truck is empty or ARV is full.

As the gantry removes pallets from the truck bed and an area is cleared, the truck is moved forward to bring additional pallets into the range of the gantry. When the entire side and center areas of the truck have been emptied of pallets, the truck is turned around to provide access to the remaining pallets. An alternative to this operation (in the case of tight quarters or limited turning area) would be to use the gantry to drag the pallets across the truck bed by hooking to the lower part of the pallet or by using the truck crane to pre-position the pallets for the gantry pickup. This last method would not extend the total time since the operation would be concurrent with the gantry movement in storing the pallets in the ARV. A time study for resupplying the ARV from the truck is shown in table 6.

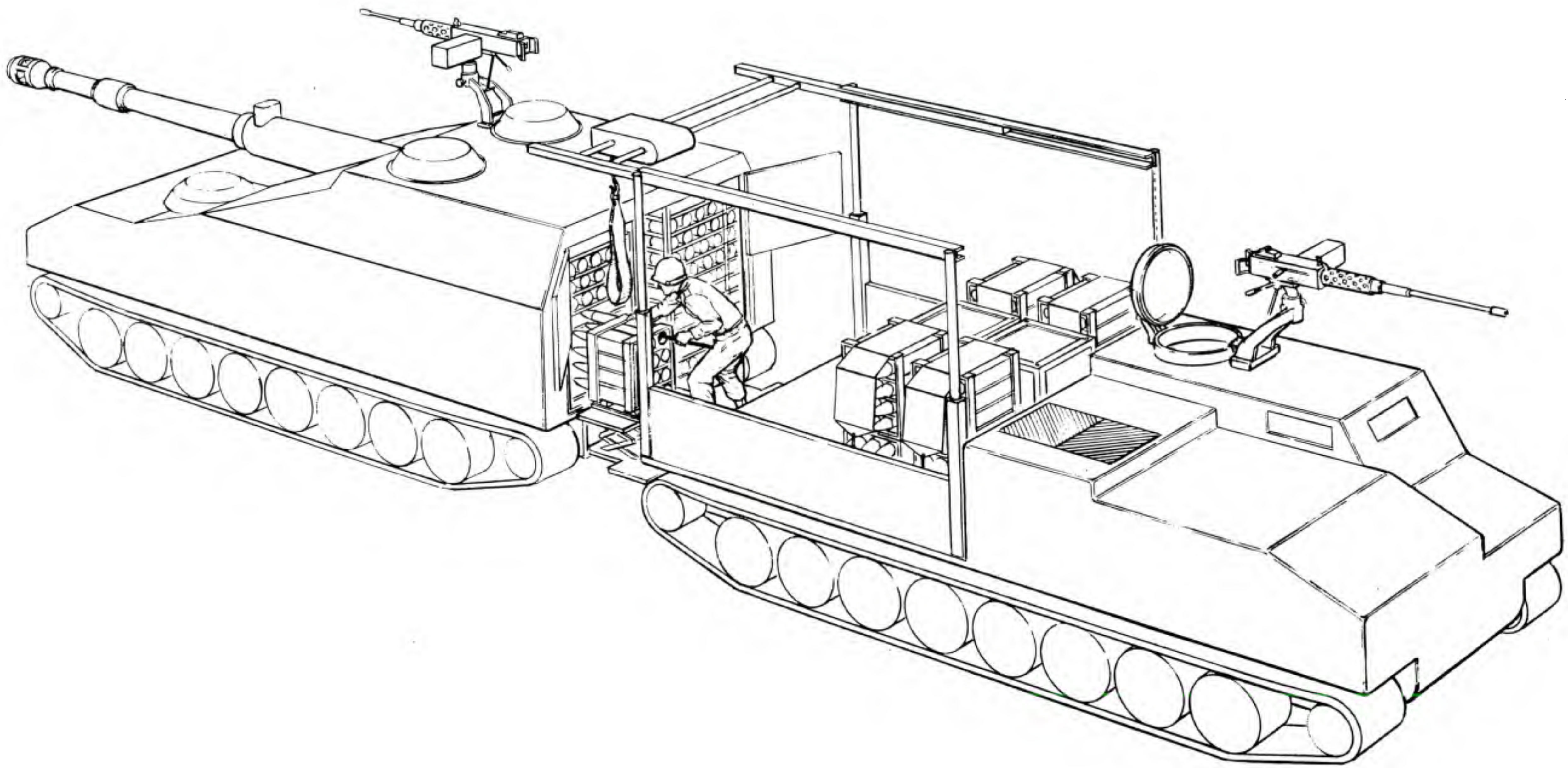


Figure 14 Transfer of Ammunition from ARV to SPH (Concept IIA)

Table 5

ARV to SPH Resupply Time (Concept IIA)

| | Operation | Time (sec) | Elapsed time (sec) |
|---|---|---|---|
| 1. | Dock the ARV with the SPH (back-to-back). Drop tailgate. Open door. | 45 | 45 |
| 2. | Pick up end pallet with gantry and position on tailgate platform. Adjust platform height to align projectiles with ready rack. | 30 | 75 |
| 3. | a. Using a ram, push each projectile into its respective rack position (12 projectiles). Dispose of pallet. | 30 | 105 |
| | b. Return gantry to ARV and pick up second pallet. Hold until platform is emptied. | (30) | ----- |
| 4. | Place second pallet on tailgate platform and adjust platform height to align projectiles with ready rack. | 30 | 135 |
| 5. | a. Load projectiles into respective slots in rack. Dispose of second pallet. | 30 | 165 |
| | b. Return gantry to ARV and pick up third pallet; hold until needed. | (30) | ----- |
| 6. | Place third pallet on platform; adjust height for loading. | 30 | 195 |
| 7. | a. Load projectiles (third pallet) and dispose of pallet. | 30 | 225 |
| | b. Return gantry to pick up fourth pallet. Hold until tailgate is cleared. | (30) | ----- |
| 8. | Place pallet on platform; adjust height for loading. | 30 | 255 |
| 9. | Load projectiles (fourth pallet); remove projectiles by hand; store beneath rack and dispose of pallet. | 30 | 285 |
| 10. | Inspect. | 15 | 300 |

Table 5

ARV to SPH Resupply Time (Concept IIA) (Cont'd)

| Operation | Time (sec) | Elapsed time (sec) |
|---|---|---|
| Propellant | | |
| 11. Return gantry to ARV to pick up two open boxes of propellant; transfer and place on tailgate. | 20 | 320 |
| 12. Hand load charge increments from both open boxes and discard boxes. | 130 | 450 |
| 13. Return gantry and pick up two additional open boxes; hold until needed. | (30) | ----- |
| 14. Place open boxes on tailgate. | 15 | 465 |
| 15. Load two open propellant boxes. | 130 | 595 |
| 16. Place extra charges (2) under rack and discard boxes. | 30 | 625 |
| 17. Inspect. Close tailgate. | 15 | 640 |
| | Total time | 10.7 min |

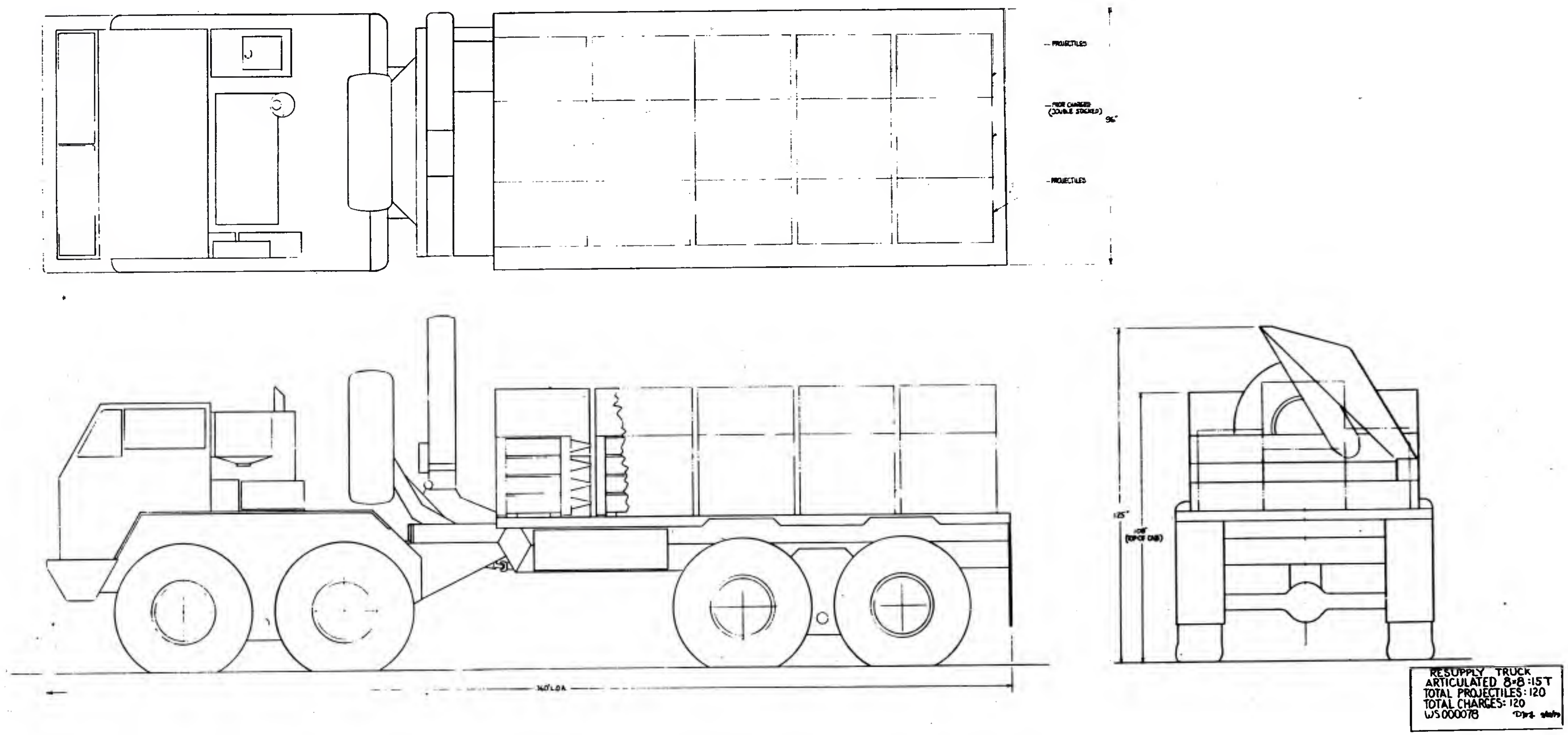



Figure 15 Resupply Truck (Concept IIA)

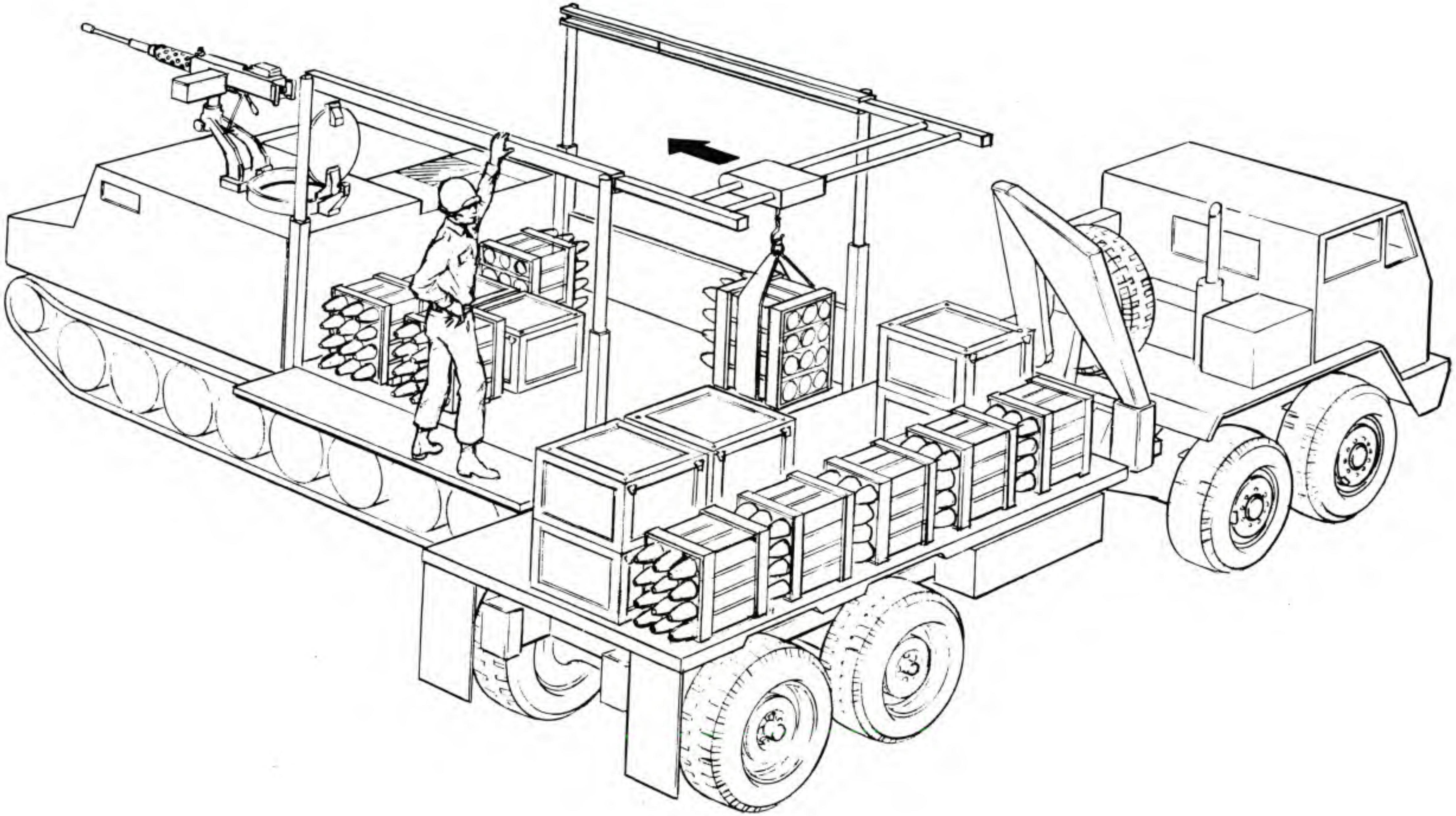


Figure 16 Transfer of Ammunition from Truck to ARV (Concept IIA)

Table 6

Truck to ARV Resupply Time (Concept IIA)

| | Operation | Time (sec) | Elapsed Time (sec) |
|---|---|---|---|
| 1. | Dock truck with ARV to form a T-configuration. | 30 | 30 |
| 2. | Extend gantry hoist over truck bed. Pick up projectile pallet and place on ARV. | 60 | 90 |
| 3. | Return gantry to truck bed. Pick up second projectile pallet; transfer to ARV. | 60 | 150 |
| 4. | Repeat steps 2 and 3 to load opposite side of ARV. | 120 | 270 |
| 5. | Return to truck, pick up two boxes of propellant charges. Transfer to ARV. | 60 | 330 |
| 6. | Repeat step 5 (twice) to transfer four propellant boxes. | 100 | 430 |
| 7. | Repeat steps 2 through 5 to transfer four pallets of projectiles and two propellant boxes. | 240 | 670 |
| 8. | Return gantry to truck and transfer two pallets of projectiles. | 90 | 760 |
| 9. | Repeat step 5. Position propellant charges on ARV. | 40 | 830 |
| 10. | Remove empty truck; dock full truck. | 30 | 860 |
| 11. | Repeat steps 2 and 3. | 90 | 950 |
| 12. | Repeat step 5. | 40 | 990 |
| 13. | Strap down pallets and stow crane. | 60 | 1050 |
| | | Total time | 17.5 min |

Note: As the truck is emptied, it is moved forward to bring the next pallet into position to be picked up by the gantry. An alternate method would be to use the truck crane to position the pallets for pickup.

ARV/Resupply Truck Crew Requirements/Functions:

ARV

Driver - Operates vehicle and assists in loading.

Ammunition handlers (2) - Prepare complete rounds for ARV/SPH interface. Load ammunition from resupply vehicle and load the SPH.

Resupply truck

Driver - Operates and maintains resupply vehicle. Also assists in loading the ARV by operating the truck-mounted crane.

Ammunition handler - Assists in transferring ammunition.

Battery Fire Control Vehicle

The battery fire direction center is mounted on a MLRS carrier and is depicted in figure 17. It is described on pages 213 through 219 .

New Turreted SPH (Concept IIB)

General

This SPH is a turreted, armored vehicle capable of 360 degree traverse operation. See figure 18 for a perspective view and figure 19 for an outline view. The overall envelope is approximately the same as the current M109 howitzer. Estimated combat weight is 70,000 pounds. Thickness of the aluminum armor is 1-1/4 inches on the top and sides, and 1/2 inch on the bottom. The vehicle is powered by a Cummins VTA-903 engine and driven by the AMX-1000 6-speed hydrokinetic transmission with bias path hydrostatic steering. Cooling of the engine is accomplished by an 8,500 cubic inch radiator with twin 18-inch diameter fans. Electric power is supplied by four 12-volt batteries. Also provided is a 25 hp diesel engine for auxiliary power. The APU is used to drive hydraulic power units, rotate the turret, and charge the electric system when the main engine is not operating.

The suspension system is a torsion bar type with the bars extending across the vehicle for increased travel. Each side of the vehicle has seven 24-inch-diameter road wheels and five hydraulic lockout units mounted on road wheels 2 through 6. The lockouts consist of a torsion housing on which are mounted the torsion bars. A hydraulic cylinder constrains the movement. The track is steel single-pin construction, and is 21 inches wide.

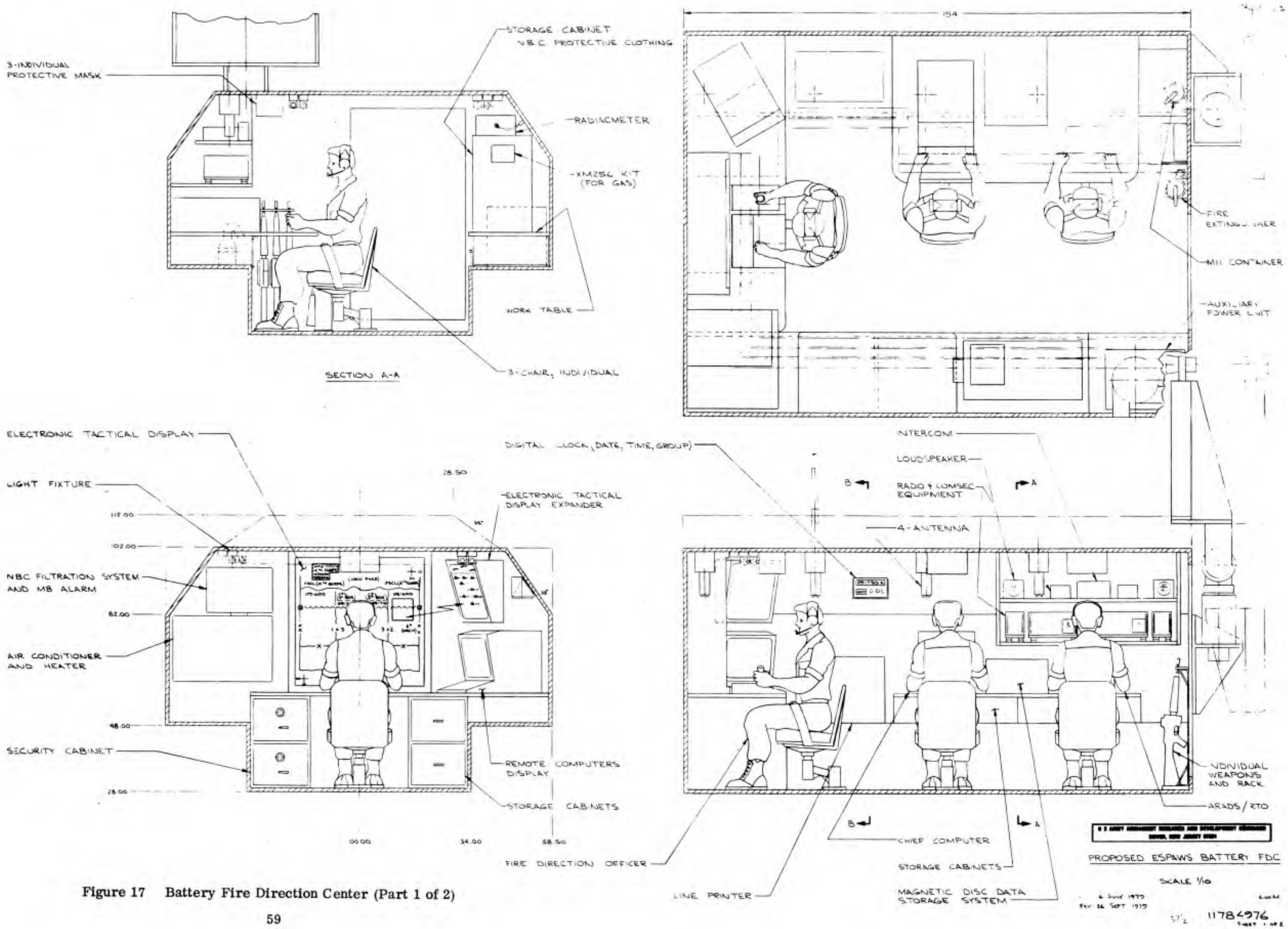



Figure 17 Battery Fire Direction Center (Part 1 of 2)

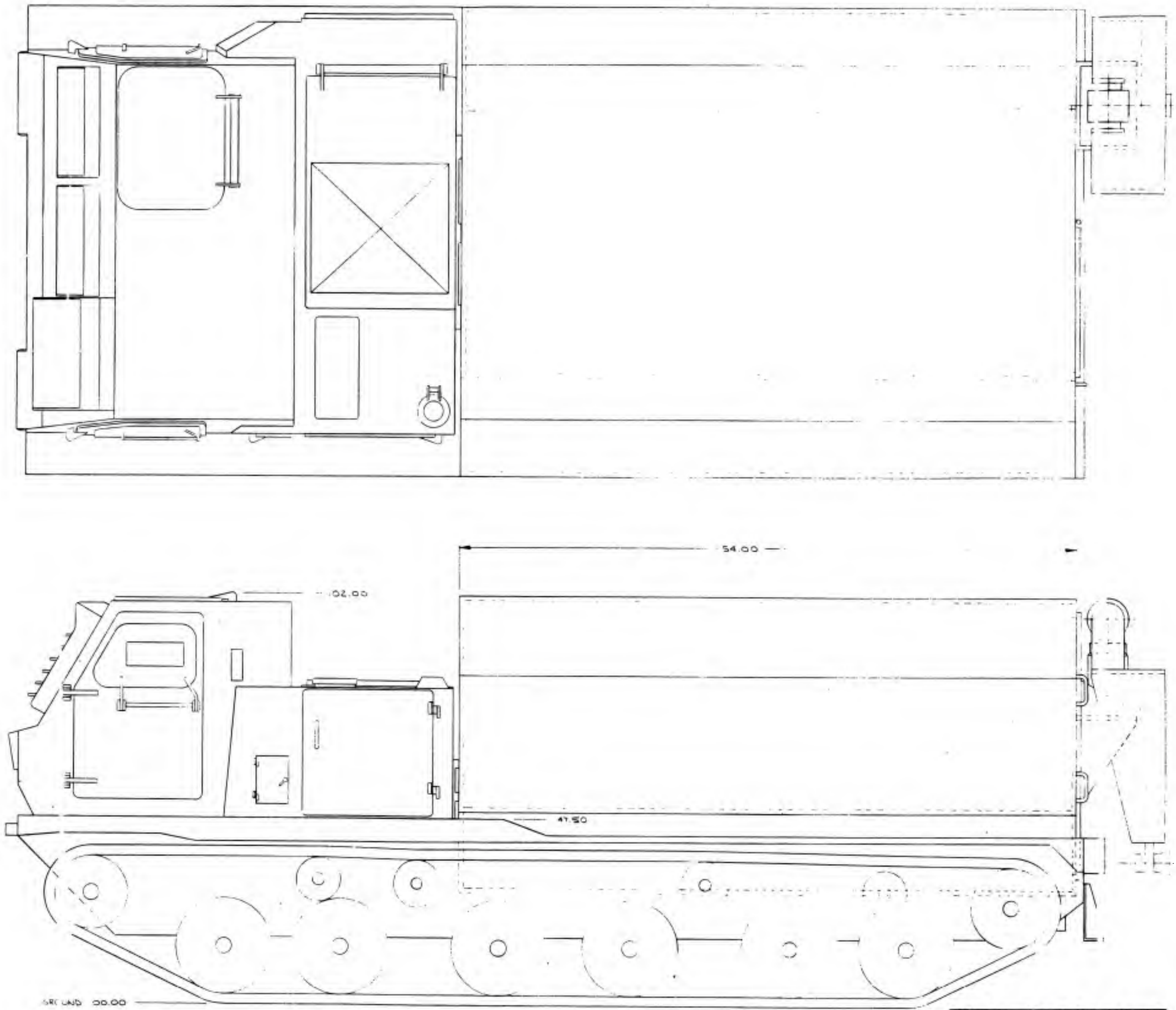



Figure 17 Battery Fire Direction Center (Part 2 of 2)

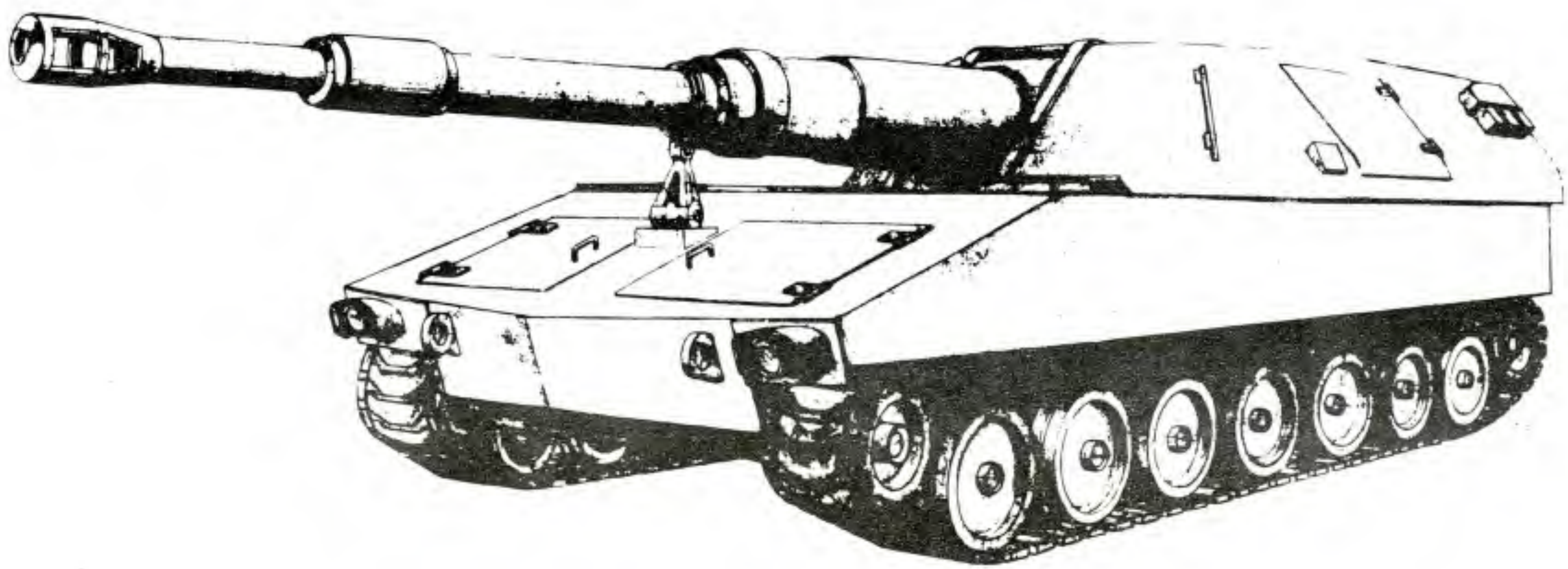


Figure 18 New Turreted SPH - Perspective View (Concept IIB)

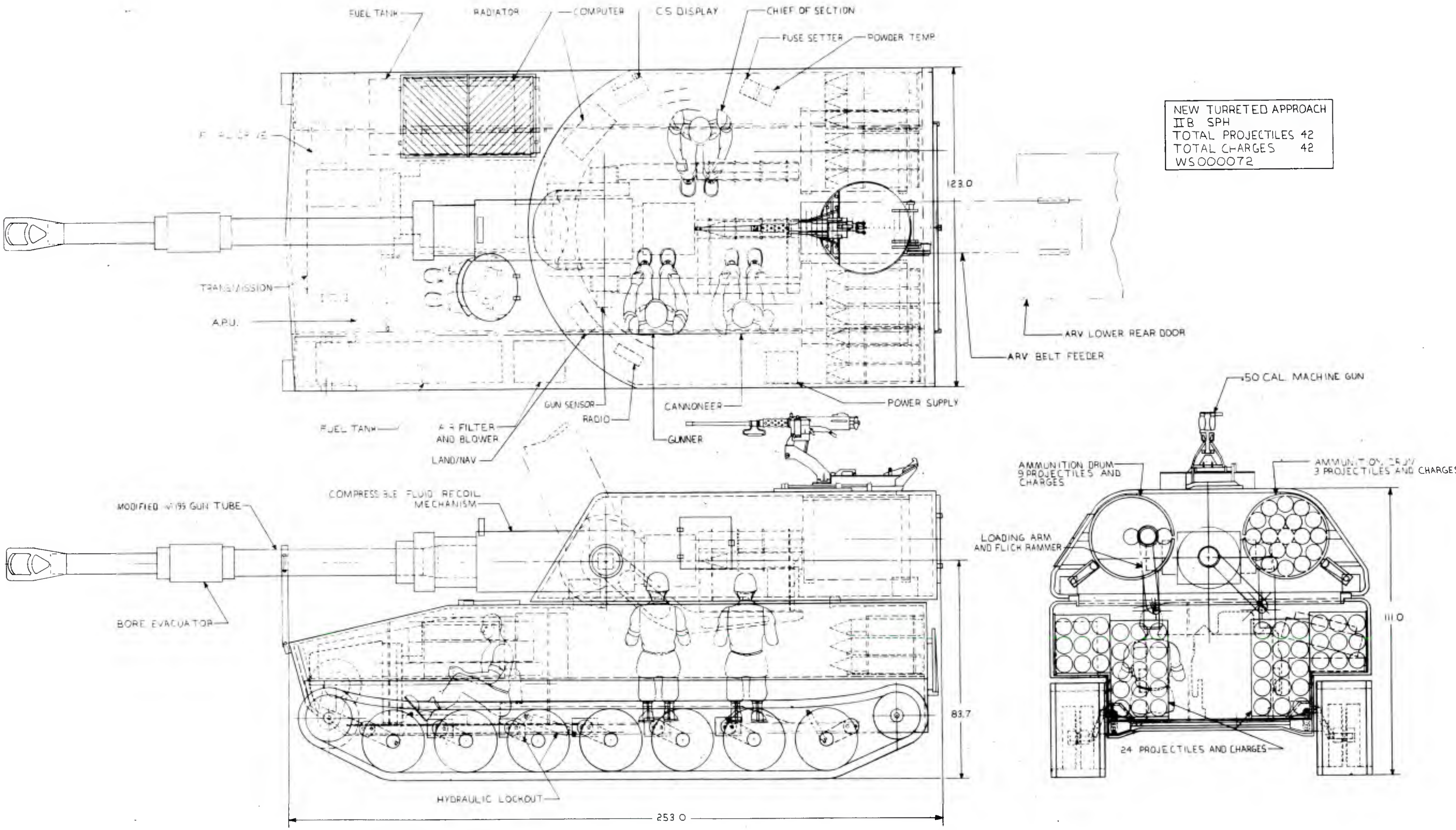



Figure 19 New Turreted SPH - Outline View (Concept IIB)

The physical and performance characteristics of this concept are summarized in tables 7 and 8, respectively.

Turret/Armament

The primary weapon system utilizes a cannon similar to the M199 with muzzle brake, bore evacuator, slide block breech, and a concentric compressible fluid recoil mechanism. The weapon can be fired from 0-to 65-degrees elevation. A hydraulic equilibration system is used to aid in elevating the gun and to minimize tube deflection during firing. A remotely activated travel lock is provided to reduce crew exposure and displace/emplace time. Fume extraction is provided by an enhanced bore evacuator capable of withstanding high rates of fire. The trunnion is located 13-inches behind the turret ring and trunnion height is 84 inches, measured from the ground.

The scatterable mine projectile will weigh between 100 and 125 pounds and will be 35 to 40 inches long. The shape will be similar to the M483 projectile. The M31 stick propellant charge will consist of four rigid, identical increments, each 6 inches in diameter, 7-1/2 inches long, and weighing approximately 6-1/2 pounds. There are three zones with the low zone being 2 increments. The ballistic range is 8,000 to 13,500 meters at charge 1 (2 increments), 11,200 to 17,700 meters at charge 2 (3 increments), and 14,000 to 22,000 meters at charge 3 (4 increments). Therefore, the overlap for charges 2 and 3 are 21-and 26-percent, respectively.

A .50-caliber machinegun is mounted on the top of the SPH. A hatch on the roof is provided for access to the machinegun. Access hatches are provided about the main power package and at the driver's compartment as well as inside the vehicle for access to all locations.

Automated Loading System

The automated loading system incorporates two rotating drums and two identical loading mechanisms for loading of projectiles and propellant charges automatically into the breech block. The rotating drums are located at the rear of the turret and are on either side of the breech block as depicted in figure 19. Each drum contains 18 longitudinally slotted tubes for ammunition component storage and transfer. Nine complete rounds are stored in each drum. The bearing-mounted drum assemblies are indexed in rotation to provide access to all rounds.

The two loading mechanisms are trunnion-mounted as shown in figure 20. The entire mechansim pivots about the gun elevation axis. This permits either of the transfer tubes, which are an integral part of each of the loading mechanisms, to rotate into direct alignment with a selected round (either in the inner or the outer ring at a specific angular position). The round selected can then be pushed into the transfer tube via a pawl and chain arrangement operated along the previously mentioned

Table 7

New Turreted Concept IIB - Physical Characteristics

| General Data | SPH | ARV | Ammo Truck |
|---|---|---|---|
| Weight | | | |
| Combat loaded (lb) | 70,000 | 64,000 | 36,086 |
| Net weight (lb) | 55,000 | 47,000 | 21,680 |
| Fuel capacity (gal) | 220 | 220 | 78 |
| Personnel | 4 | 3 | 2 |
| Dimensions | | | |
| Length (in) | 251 | 251 | 317 |
| Width (in) | 123 | 123 | 92 3/4 |
| Height (in) | 111 | 114 | 85 1/2 |
| Ground clearance (in) | 18 | 18 | 10 1/2 |
| Wheel size (in) | 24 | 24 | 11Rx20 |
| Track width (in) | 21 | 21 | 6-wheel drive |
| **Firepower** | | | |
| Armament | 155mm cannon, .50-cal mg | .50-cal mg | |
| Elevation/depression (deg) | 65/0 | | |
| On-board traverse (deg) | 360 | | |
| Breech type | Slide block | | |
| Number of rounds carried | 42 | 96 | 120 |
| Family of projectiles | Scatterable mine/ICM/HE | Scatterable mine/ICM /HE | Scatterable mine/ ICM/HE |
| Type of ammo handling | Auto load/auto ram | Power assist (hoist, conveyor) | Power assist (crane) |
| **Mobility** | | | |
| Suspension | Full width torsion bars | Full width torsion bars | Tapered leaf |
| Lockout on suspension | Yes | No | No |

Table 7

New Turreted Concept IIB - Physical Characteristics (Cont'd)

| General Data | SPH | ARV | Ammo Truck |
|---|---|---|---|
| Automotive | | | |
| Engine | Cummins VTA-903 | Cummins VTA-903 | Cummins NHC-250 |
| Transmission | AMX-1000 | AMX-1000 | 5-speed manual sychromesh |
| Survivability | | | |
| Armor protection (in) | Similar to M109 | Similar to M109 | |
| NBC protection | Hybrid | Hybrid | Ventilated facepiece |

Table 8

New Turreted Concept IIB - Performance Characteristics

| | SPH | | ARV | | Ammo Truck | | Battery |
|---|---|---|---|---|---|---|---|
| **Firepower** | | | | | | | |
| Min/max range (km) | | | | | | | |
| Scatterable mine | 8-22 | | | | | | |
| ICM (RAP) | 8-22 (30) | | | | | | |
| HE (RAP) | 8-22 (30) | | | | | | |
| Shoot and scoot respose | | | | | | | |
| Firing rate | 18 rds/2.2 min | | | | | | |
| .5 to 2 km relocation time (min) | 15 | | | | | | |
| Max weapon missions/hour | 3 | | | | | | |
| TLE (m) | 85 | | | | | | |
| Battery ammunition usage (rds/day) | | | | | | | |
| 17 targets/hour | 7,344 | | | | | | |
| Max firing rate | 10,368 | | | | | | |
| **Ammunition Supply** | | | | | | | |
| Basic load (rds) | 8X42 | + | 8X96 | + | 6X120 | = | 1,824 |
| Ammunition resupply (min) | 11 | | 9 | | | | |
| Battery resupply rate (17 trucks at battery) | | | | | | | |
| 40% ASP/60% ATP (rds/day) | | | | | | | 4,640 |
| 100% ATP (rds/day) | | | | | | | 8,160 |
| **Mobility** | | | | | | | |
| Cruising range (km) | 465 | | 500 | | 460 | | |
| Hp/ton | 17.8 | | 19.5 | | 14 | | |

Table 8

New Turreted Concept IIB - Performance Characteristics (Cont'd)

| | SPH | ARV | Ammo Truck | Battery |
|---|---|---|---|---|
| Max speed-primary roads (kph) | 60 | 65 | 70 | |
| Ground pressure (psi) | 9.6 | 8.7 | 21 | |
| Max grade (%) | 60 | 60 | 60 | |
| Verticle obstacle (m) | 0.64 | 0.64 | -- | |

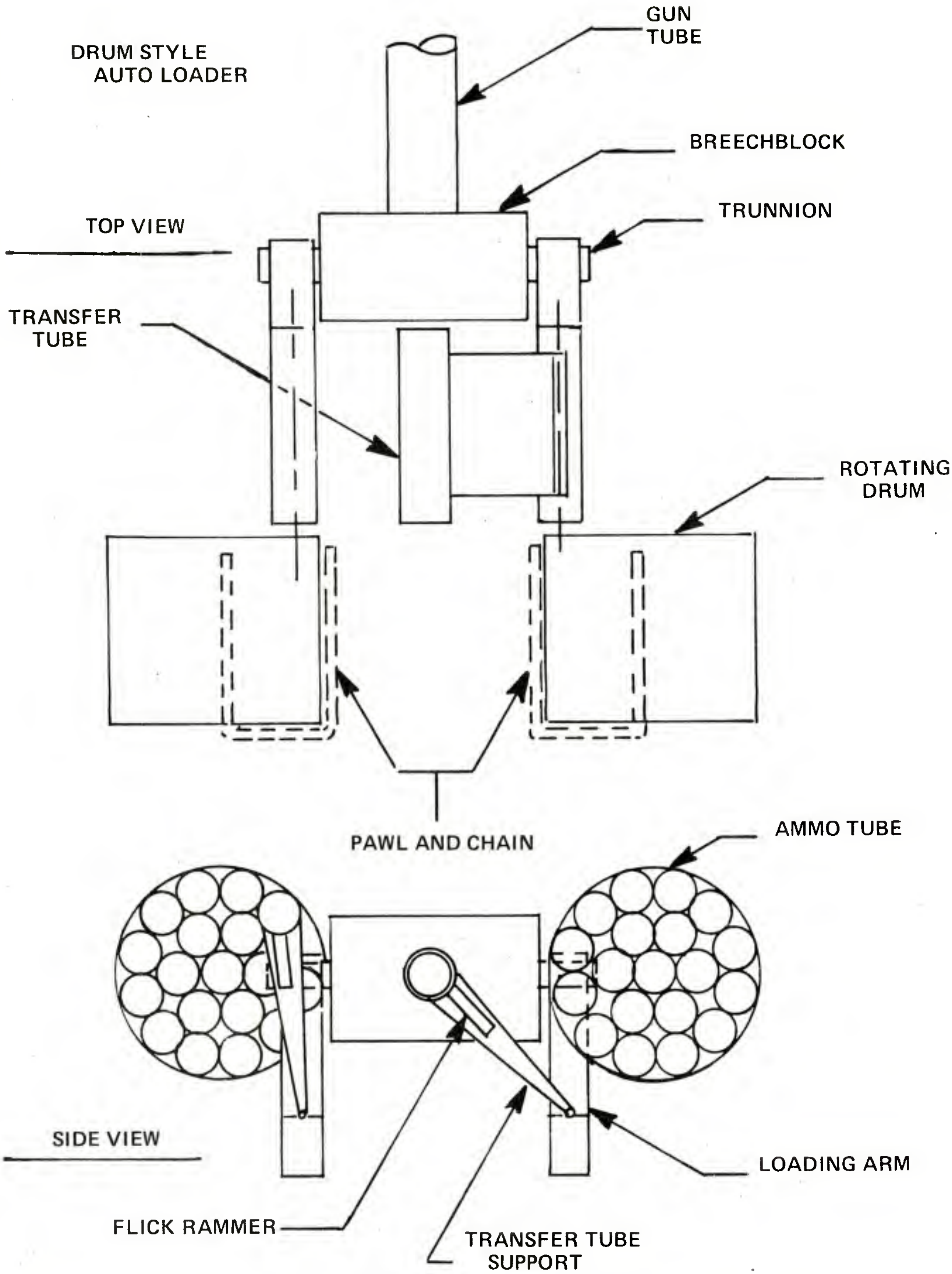



Figure 20 Trunnion-Mounted Loading Mechanism (Concept IIB)

slots. A similar action takes place in the other drum/loading mechanism for the propellant charge selected.

By rotating the entire loading mechanism to a position parallel to the gun axis, the transfer tube support can be rotated about an axis parallel to the gun, bringing the projectile directly behind the breech block. An integral flick rammer seats the projectile. Once the projectile has been loaded into the breech block, this mechanism swings back to an upright position and the other mechanism repeats the process for the propellant charge. When both supports are upright, sufficient room is available for recoil. The maximum firing rate is anticipated to be 18 rounds in 2.2 minutes. See figure 21 for an operational view of the autoloader.

Upon firing, projectile velocity is measured by a velocimeter and the data is fed into an on-board fire control computer which determines the desired fuze setting. The fuze, which is energized by a magnetic setback generator, now receives its correct setting via a RF signal initiated by the computer.

The advantages of the drum-type automatic loading system are:

a. Any round in the drum can be indexed to the loading position.

b. Simple in design; only rotational and linear motions are involved in the system.

c. Automatic operation will not restrict 360 degree traverse or 0-to 65-degree elevation movements.

d. Various modes of operation: As an alternative to the on-board drums, ammunition could also be loaded into the transfer tube directly from the ARV by using a conveyor through the turret or chassis opening. When the round is fed through the chassis door, the ammunition would be picked up manually and placed into the transfer tube for ramming.

The shortcomings of the concept are that considerable space is required to accommodate the entire loading system; loading capacity and space for crew functions are limited.

Fire Control and Communication Equipment

The heart of the on-board fire control system is the ballistic computer. It receives weapon position data from a land navigation subsystem, gun pitch, roll, and direction from the gun sensors, meterological data from MET MESSAGE, propellant charge temperature from the propellant charge monitor, and the fire mission from the battery FDC. Through a digital message device, the computer activates the

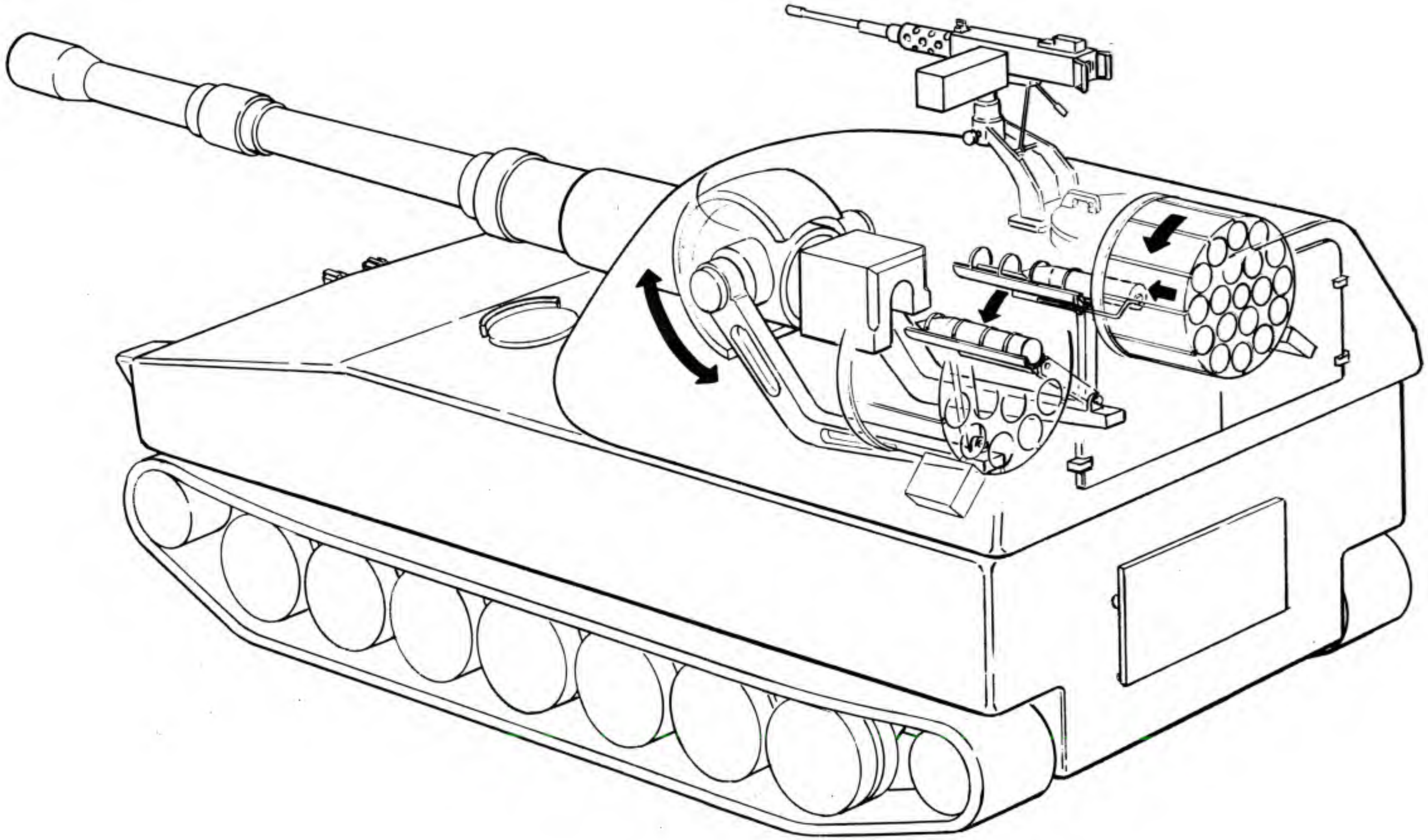


Figure 21 Operational View of Autoloader (Concept IIB)

automated loading system for selection of propellant charge and desired projectile from the ready rack. After the gun has been loaded and automatically laid to the calculated azimuth and elevation, the chief of section display indicates the actual weapon settings compared to the specific fire commands. The computer will disable the weapon unless proper verification is made. Arrangement of the fire control computer, velocimeter, land navigation system, gun sensors, fuze setter, radio, chief of section display, and power package are shown in the SPH layout (figure 19).

NBC Protection

A ventilated facepiece is employed. A positive pressure system may be utilized. Using a hybrid system, the SPH can fire 42 rounds before it becomes necessary to resupply. Resupply would take place in a prearranged "clean" area an appropriate distance from any contaminated area.

SPH Crew Requirements/Functions:

Driver - Operates and maintains vehicle and assists with ammunition handling.

Chief of section - In charge of communication, coordination, etc.

Gunner - Operates fire control system.

Cannoneer - Controls loading mechanism; places a complete round manually into the transfer tube for ramming, if required.

Ammunition Resupply Vehicle (ARV)

The automotive aspect of the ARV is identical to that of the SPH. One and a quarter inches of aluminum armor is provided for ammunition and crew protection. NBC protection is the same the SPH. The overall envelope of the vehicle is shown in figure 22. Note the arrangement of pallets for 96 projectiles and containers for propellant charges.

The ARV is provided with side and rear doors to facilitate simultaneous loading of projectile pallets and propellant charge containers. The side door is in three sections which match the armor profile. The middle and the upper sections are hinged on the armor. The lower section is mounted on the sponson. In the open position, the lower section serves as a platform for receiving ammunition from the supply truck. The rear door consists of two sections. The upper section, hinged at the roof, provides ballistic protection while loading operations take place. The lower section is actually a hydraulic lift gate which provides height adjustment for receiving ammunition from the supply truck and for replenishing the ready rack of the SPH.

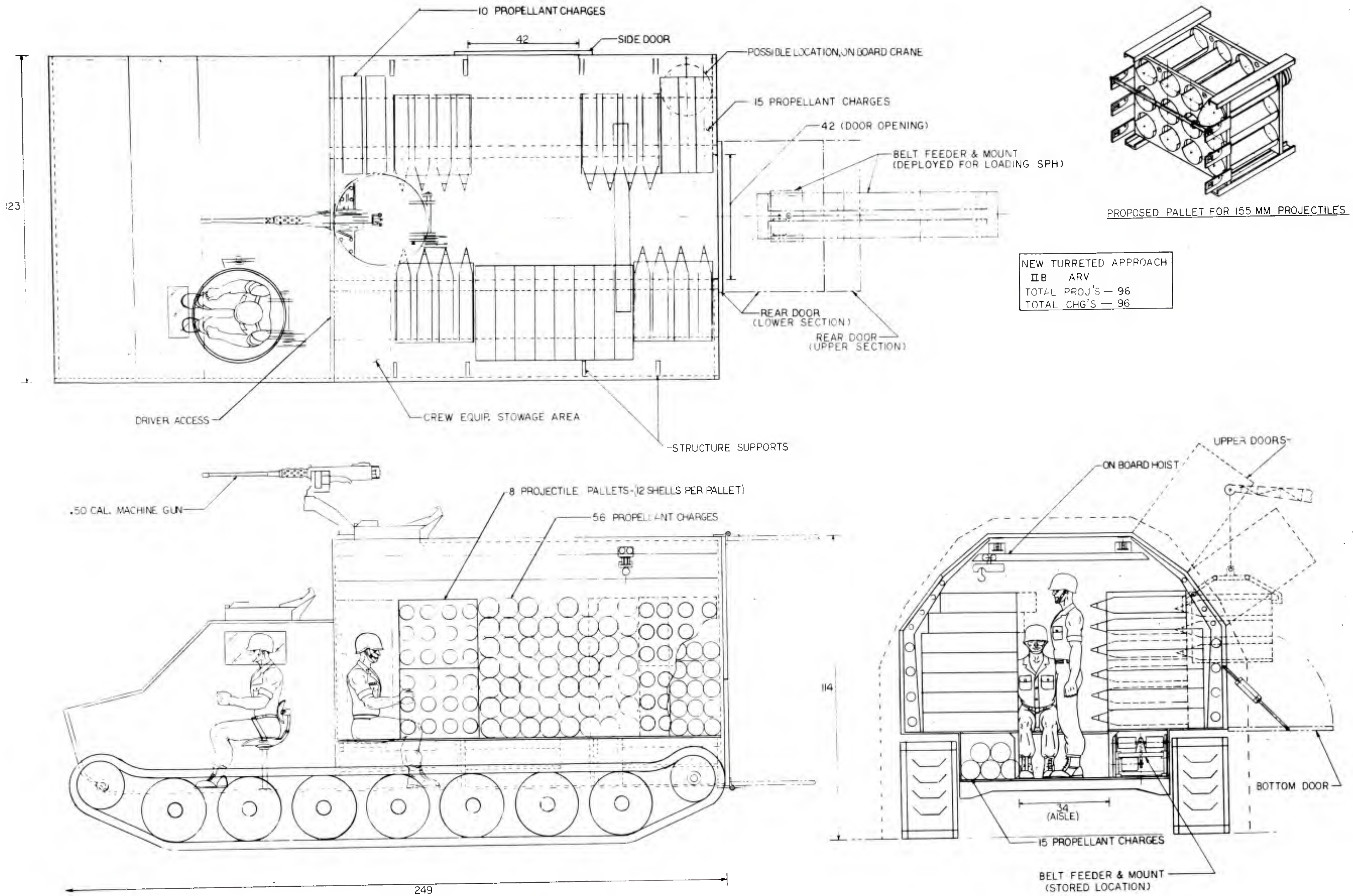



Figure 22 ARV for New Turreted SPH (Concept IIB)

The ARV is equipped with a three-degrees-of-freedom hoist, or gantry, mounted on the ceiling and receives projectile pallets from the side door section (the platform), or the tailgate. There is also a dismountable conveyor for handling ammunition between the ARV and SPH. By docking the ARV to the SPH (back-to-back) and opening the rear doors of the two vehicles, the conveyor can be quickly mounted on the lift gate of the ARV. With the aid of the cantilever-mounted conveyor (powered by an electric motor), a ready service round can be loaded into either of the SPH loader drums, be transferred directly into the transfer tube through the turret opening, or to the SPH chassis through its rear door. See figure 23 for a view of the transfer of ammunition. Traverse degree of freedom permits the conveyor to follow the turret up to a certain limited angle to faciliate the ammo handling process. Height adjustment is accomplished by the up-and-down motion of the tailgate. The conveyor may also be moved in and out with respect to its structure mount (or with respect to the ARV) for maximum extension and retraction. A time study for resupplying the SPH from the ARV is presented in table 9.

Resupply Truck

Resupply of the ARV is accomplished at a rendezvous point where an M813 supply truck may be docked to unload ammunition from either side or the rear of the vehicle onto the side door (platform), or onto the tailgate of the ARV. Ammunition is handled inside the ARV with the aid of the hoist. While a crewman (e.g. the ARV driver) is operating the hoist to store the projectile pallet, ammunition handlers break down the propellant charge pallet unloaded onto the tailgate and store the propellant charges (in containers) to the proper locations in the ARV.

The supply truck is equipped with an on-board crane capable of lifting palletized ammunition from the truck bed to the ARV. See figure 24. Control of the crane is accomplished by a control box tied to the crane via wire. This allows the crane operator (the M813 truck driver) to control the loading operation from numerous vantage points. A time study for resupplying the ARV from the truck is shown in table 10.

ARV/Resupply Truck Crew Requirements/Functions:

ARV

Driver - Operates and maintains the vehicle; assits in ammunition handling.

Ammunition handlers (2) - Prepare complete rounds for ARV/SPH interface; are responsible for receiving ammunition unloaded from supply truck.

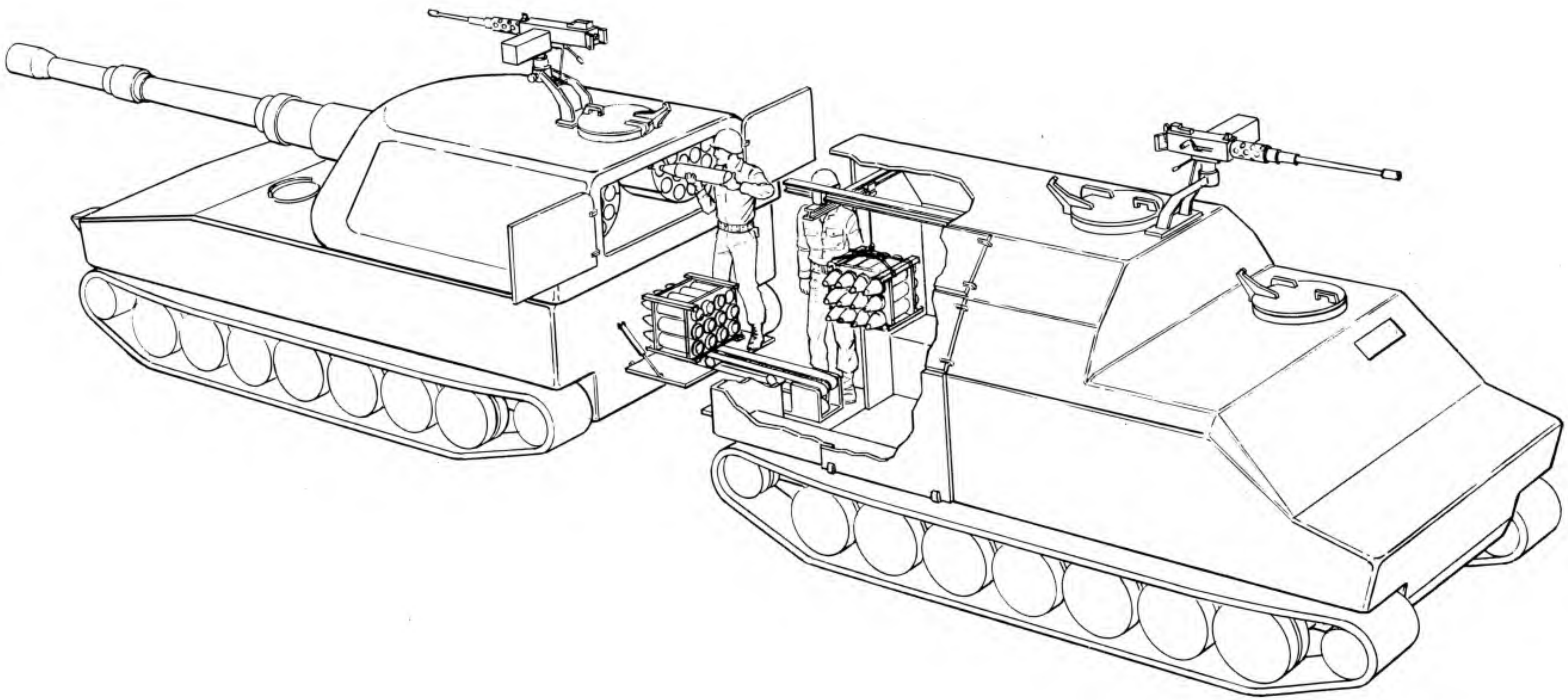
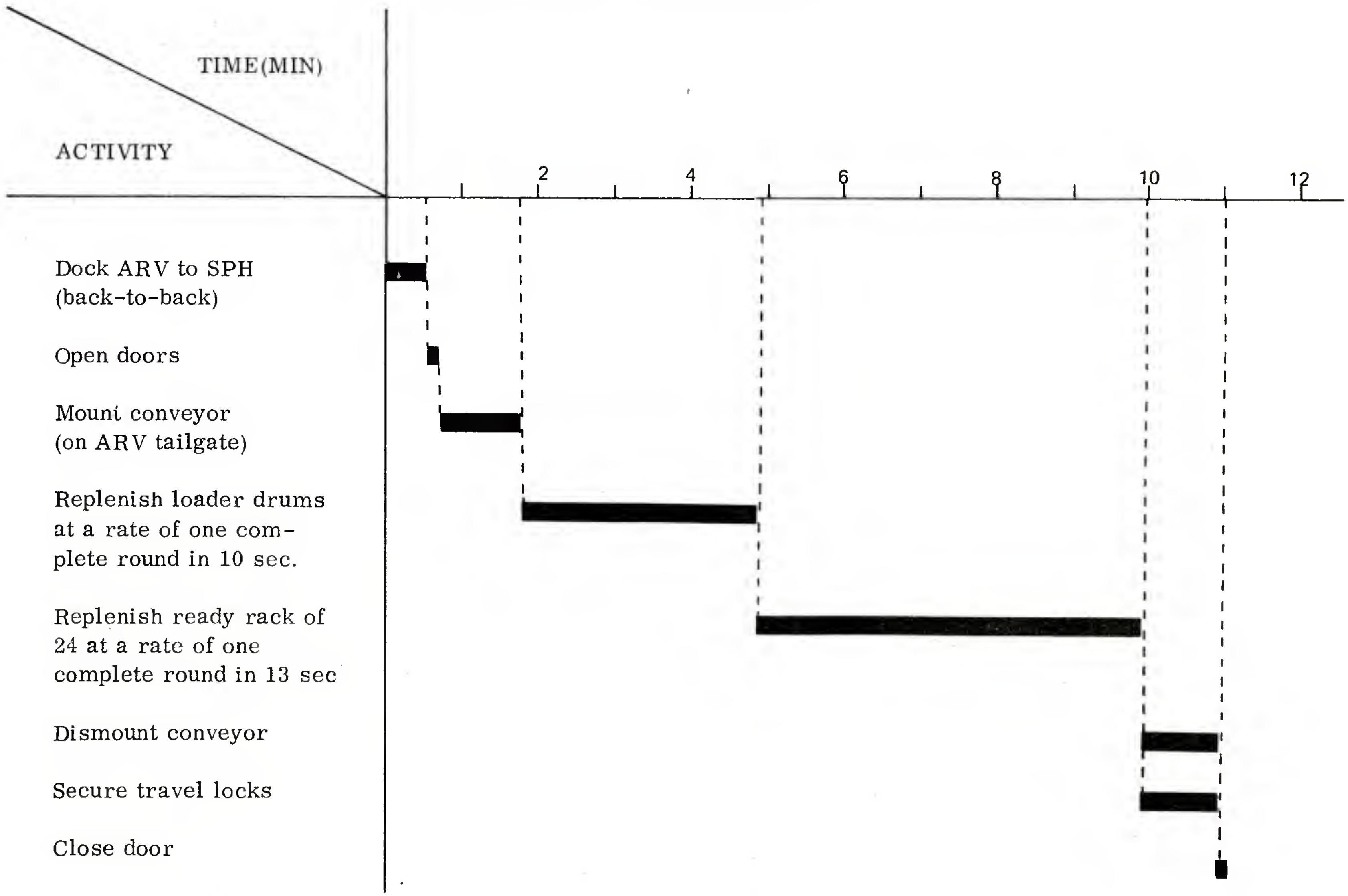


Figure 23 Transfer of Ammunition from ARV to SPH (Concept IIB)

Table 9

ARV to SPH Resupply Time (Concept IIB)



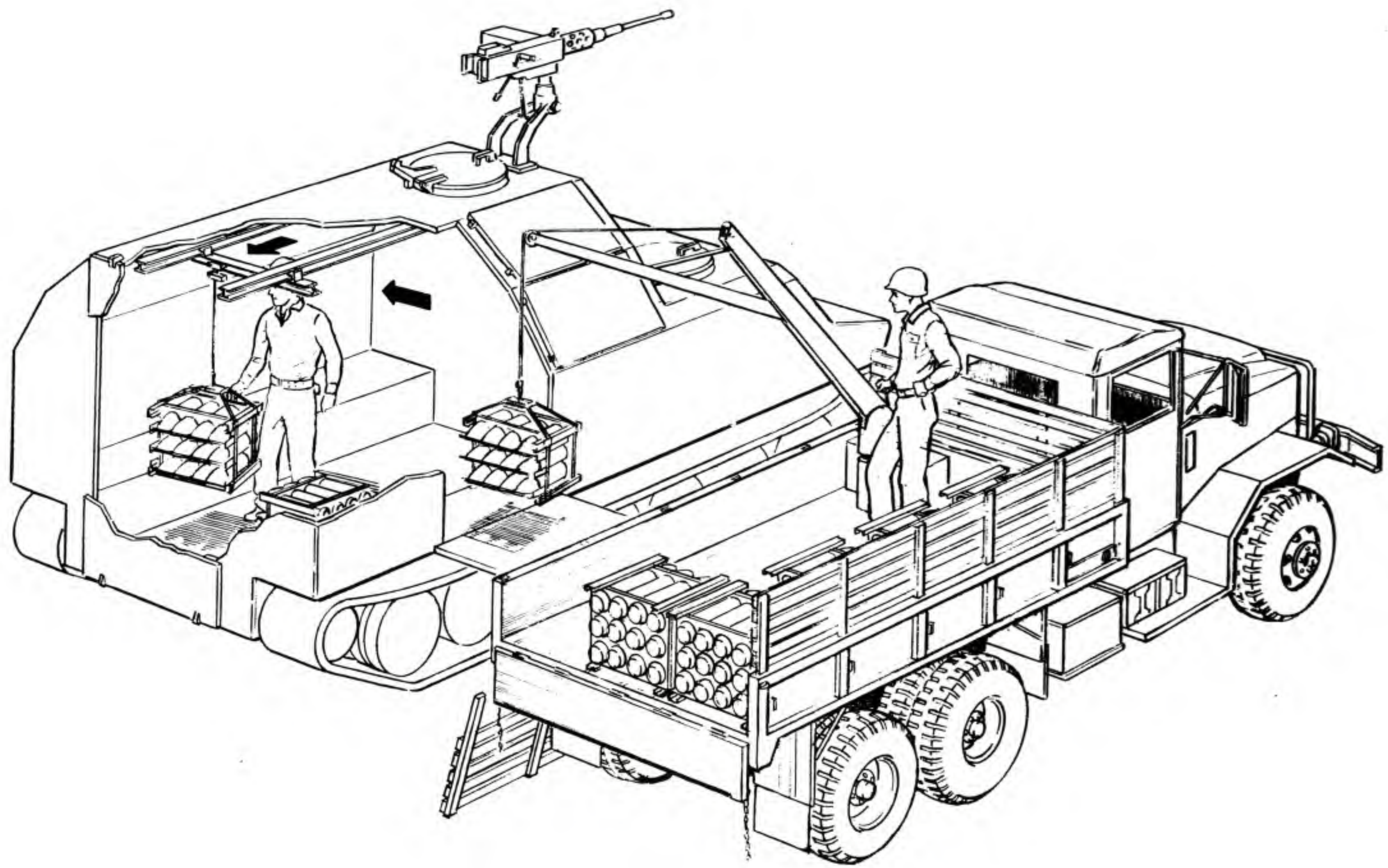
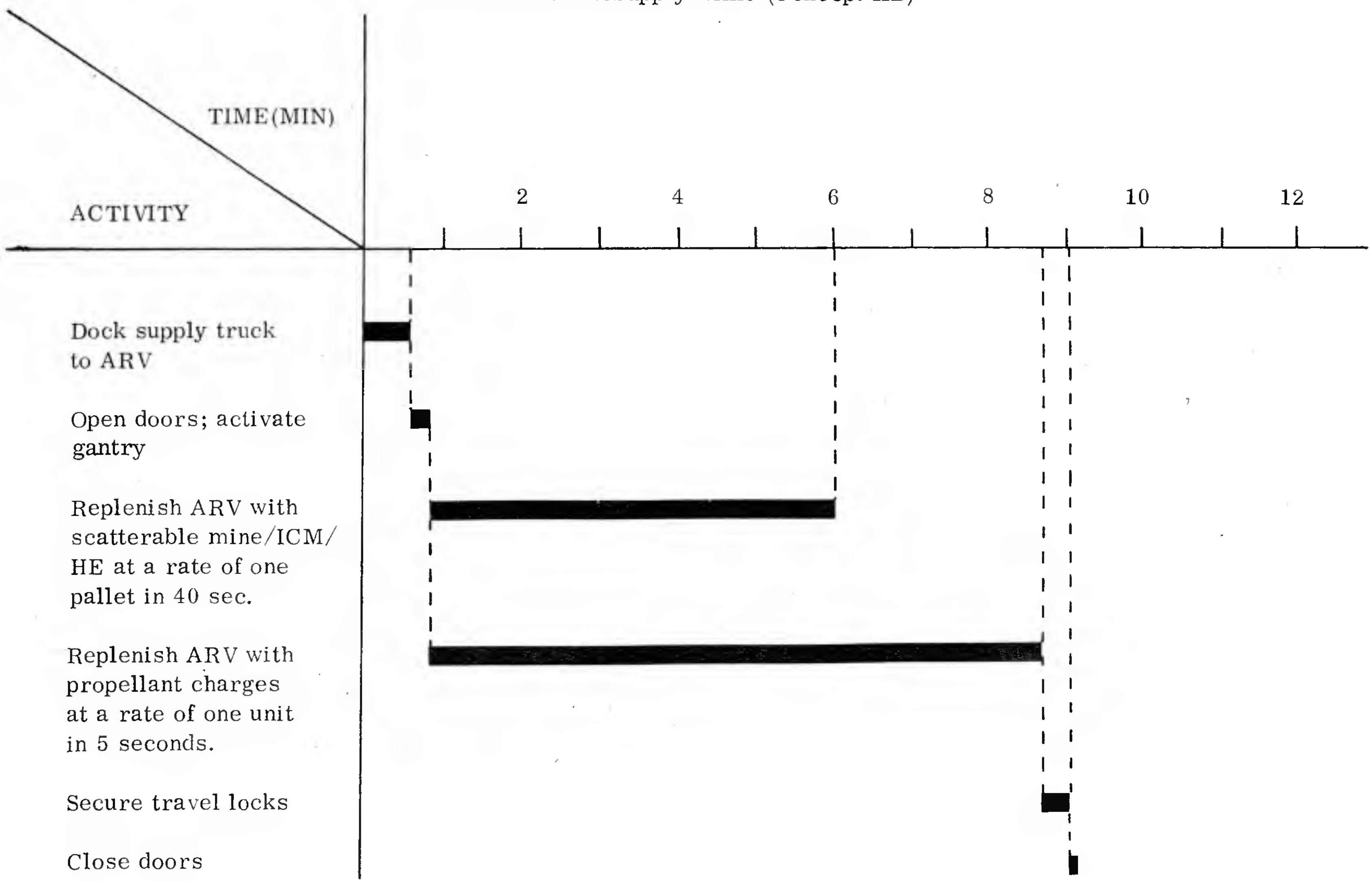


Figure 24 Transfer of Ammunition from Truck to ARV (Concept IIB)

Table 10

Truck to ARV Resupply Time (Concept IIB)



Resupply truck

Driver - Operates and maintains the truck; unloads ammunition from the truck to the ARV.

Ammunition Handler - Assists in transferring ammunition.

Battery Fire Control Vehicle

The battery fire direction center is mounted on a MLRS carrier and is depicted in figure 17. It is described on pages 213 through 219 .

Enhanced M109A2 SPH (Concept IIC)

General

The enhanced M109A2 SPH (figure 25) is a full-tracked, armored, air-transportable, diesel-powered vehicle which carries 44 rounds. Its aluminum armor is 1-1/4 inches thick on the top and sides and 1/2-inch thick on the bottom. With its semiautomatic loader it is capable of firing the complete range of conventional and nuclear ammunition at a maximum rate of 18 rounds in 2 minutes. A suspension lock-out system provides a stable firing platform and eliminates the need for spades.

An APU is positioned in the right rear area of the hull. It supplies 25 kw of electrical power for the automatic gun laying system, NBC protection system, land navigation system, communication system, projectile rammer, and the support systems necessary to the firing mission. This permits shutdown of the main engine when firing. The APU is powered by a gas turbine which uses diesel fuel from the main engine tanks.

The SPH utilizes the 500 hp Detroit Diesel 8V71T engine and Ordinance torque converter XTG-411-2A. An increase in engine cooling capacity and a change in fuel injection raises the horsepower from 405 to 500.

The physical and performance characteristics of this concept are summarized in tables 11 and 12, respectively.

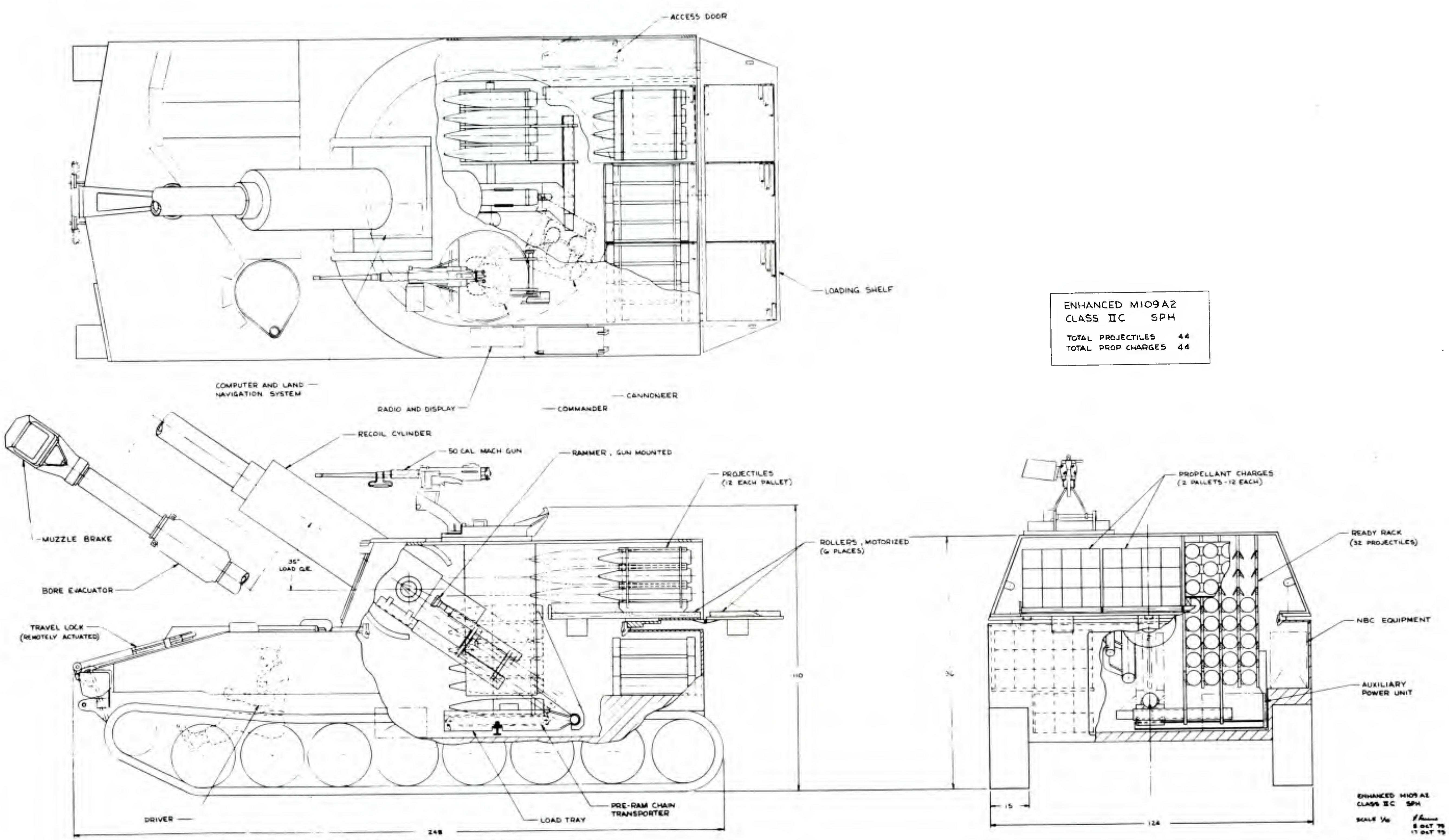



Figure 25 Enhanced M109A2 SPH (Concept IIC)

Table 11

Enhanced M109A2 Concept IIC - Physical Characteristics

| General Data | SPH | ARV | Ammo Truck |
|---|---|---|---|
| Weight | | | |
| Combat loaded (lb) | 59,000 | 54,000 | 51,000 |
| Net weight (lb) | 53,000 | 38,000 | 27,800 |
| Fuel capacity (gal) | 135 | 163 | - |
| Personnel | 3 | 2 | 2 |
| Dimensions | | | |
| Length (in) | 248 | 277 | 339 |
| Width (in) | 124 | 117 | 96 |
| Height (in) | 110 | 112 | 134 |
| Ground clearance (in) | 18 | 17 | 14 |
| Wheel size (in) | 24 | 24 | 53 |
| Track width (in) | 15 | 21 | 8-wheel drive |
| **Firepower** | | | |
| Armament | 155mm cannon<br>.50-cal mg<br>M16 rifles (3) | .50-cal mg<br>M16 rifles (2) | M16 rifles (2) |
| Elevation/depression (deg) | +73/-3 | | |
| On-board traverse (deg) | 360 | | |
| Breech type | Slide block | | |
| Number of rounds carried | 44 | 96 | 120 |
| Family of projectiles | Scatterable mine/ICM/HE | Scatterable mine/ICM/HE | Scatterable mine/ICM/HE |
| Type of ammo handling | Auto load projectile<br>Hand load propellant | X-Y trolly | Crane |

Table 11

Enhanced M109A2 Concept IIC - Physical Characteristics (Cont'd)

| General Data | SPH | ARV | Ammo Truck |
|---|---|---|---|
| **Mobility** | | | |
| Suspension | Full width torsion bar | Return roller torsion bar | Tapered leaf |
| Lockout on suspension | Yes | | |
| Automotive | | | |
| Engine | Detroit Diesel 8V71T | Cummins VTA-903 | Detroit Diesel 8V92TA |
| Transmission | XTG-411-2A | GE HMPT-500 | Allison HT 740D |
| **Survivability** | | | |
| Armor protection (in) | 1.25 aluminum | 1.25 aluminum | - |
| NBC protection | Ventilated facepiece | Ventilated facepiece | Ventilated facepiece |

Table 12

Enhanced M109A2 Concept IIC - Performance Characteristics

| | SPH | | ARV | | Ammo Truck | | Battery |
|---|---|---|---|---|---|---|---|
| **Firepower** | | | | | | | |
| Min/max range (km) | | | | | | | |
| Scatterable mine | 8-22 | | | | | | |
| ICM (RAP) | 8-22 (30) | | | | | | |
| HE (RAP) | 8-22 (30) | | | | | | |
| Shoot and scoot response | | | | | | | |
| Firing rate | 18 rds/2.0 min | | | | | | |
| .5 to 2 km relocation time (min) | 15 | | | | | | |
| Max weapon missions/hour | 3 | | | | | | |
| TLE (m) | 85 | | | | | | |
| Battery ammunition usage (rds/day) | | | | | | | |
| 17 target/hour | 7,344 | | | | | | |
| Max firing rate | 10,368 | | | | | | |
| **Ammunition Supply** | | | | | | | |
| Basic load (rds) | 44X8 | + | 96X8 | + | 120X6 | = | 1,840 |
| Ammunition resupply (min) | 5.5 | | 6.5 | | | | |
| Battery resupply rate (17 trucks at battalion) | | | | | | | |
| 40% ASP/60% ATP (rds/day) | | | | | | | 4,640 |
| 100% ATP (rds/day) | | | | | | | 8,160 |

Table 12

Enhanced M109A2 Concept IIC - Performance Characteristics (Cont'd)

| | SPH | ARV | Ammo Truck | Battery |
|---|---|---|---|---|
| **Mobility** | | | | |
| Cruising range (km) | 320 | 480 | 600 | |
| HP/ton | 16.9 | 18.5 | 17.3 | |
| Max speed-primary roads (kph) | 60 | 64 | 93 | |
| Ground pressure (psi) | 10.3 | 7.5 | 15.5 | |
| Max grade % | 60 | 60 | 60 | |
| Verticle obstacle (m) | 0.53 | 0.9 | 0.45 | |

### Turret/Armament

The primary armament is a modified M199 155mm cannon with a bore evacuator and slide breech block. A compressible fluid concentric recoil mechanism is used instead of the conventional multiple cylinder mechanism employing a recoil brake and recuperator. Recoil length is anticipated to be approximately 20 inches with a 120,000 pound peak trunnion load. This compressible fluid recoil mechanism encompasses approximately the same envelope as the current M178 mount. Therefore, no extensive modifications to the cab are required.

The traverse and equilibrator mechanisms are the same as the present M109A2 configuation but the elevating mechanism is altered. The present M109A2 equilibration/elevation cylinder is used for equilibration purposes only and elevation is accomplished by an electrically powered gear drive system mounted on the turret ring adjacent to the mount rotor. This eliminates the problem of cab roof cracks associated with the present configuration. The cannon may be fired at elevations from -3 degrees to +75 degrees.

Air defense and target suppression is accommodated by a .50-caliber machinegun mounted on the cab roof.

### Automated Loading System

Normal loading is accomplished with rounds from the turret-mounted ready rack. Selection is made from one of four columns, the bottom round dropping to the load tray. The remaining rounds in the column are individually sequenced down to the next position. The load tray retainer grips the projectile as it moves horizontally to the centerline of the gun. The load tray then tilts up from a rear pivot point to a fixed 35-degree load angle. Proper alignment with the gun is assured when a sensor acknowledges contact between the load tray and the breech. The sensor actuates a pre-ram chain transporter which places the projectile into the breech. A gun-mounted rammer than swings into position, rams the projectile, and returns to a retracted position. Upon activation of the ram stroke, the load tray returns to the starting position beneath the ready rack. The gun is free to move to the desired elevation during the ramming cycle. When the rammer is fully retracted, the propellant charge is placed into the breech and inserted by hand. The breech is closed and the gun is fired to complete the cycle. A burst of 18 rounds in 2 minutes, with one man loading propellant charges, has been established for this concept. This rate of fire provides the proper density of mines to kill the targets.

The propellant charge is a rigid, 155mm full-charge M31 stick propellant with circumferential rip cords along its length for selection of the desired zone. The charge as supplied is used for the top zone; up to two segments can be removed and discarded (by pulling the proper rip-cord) to obtain lower zones in this three-zone solution. The low zone ballistic range is 8 to 13.5 km, intermediate zone ballistic range is 11.2 to 17.7 km, and the full zone ballistic range is 14.1 to 22 km. Therefore, the overlap for the intermediate and full zones is 21-and 26-percent, respectively. The charges are shipped and stowed in square-end cans. These interlocking cans are banded into 12-charge pallets.

### Chassis/Suspension

The M109 hull is extended rearward as far as the bustle rack. This provides additional stowage space for ammunition, control systems, crew article storage, and an auxiliary power unit. The rear idler wheels are eliminated and replaced with a road wheel. This addition of the road wheel increases ground contact length by approximately 28 inches, for a total ground contact length of 182 inches. Based upon a tread width of 109 inches, this provides a track length-to-width ratio of 1.67.

Modifications are made to the torsion bar system. Currently, the torsion bars extend one-half the hull width on roadwheels 3 through 6, and five-eights the hull width on roadwheels 1, 2, and 7. The modification entails extending the torsion bar on all roadwheels to the full width of the hull. Anchoring is accomplished by moving the existing anchors as close to the arm housings as possible. This modification improves RAM characteristics and provides a baseline configuration which will be compatible with future vehicle modifications.

An additional suspension modification is the inclusion of a suspension lockout system. The lockouts, which are terrain adjustable and hydraulically actuated, are integrated with the shock absorber system. The addition of a suspension lockout system allows the deletion of the firing spades and enables rapid enplacement and displacement.

### Fire Control and Communication Equipment

The heart of the on-carriage fire control system is the ballistic computer. It receives weapons location data from a land navigation subsystem, gun pitch, roll, and direction from gun sensors, meterological data from MET MESSAGE, propellant charge temperature from the propellant charge monitor, and the fire mission from the battery FDC. Through a digital message device, the computer instructs the cannoneer as to the selected propellant charge. The autoloader selects the desired projectile from the ready rack. After the gun has been loaded and automatically laid to the calculated azimuth and elevation, the chief of section display indicates the actual weapon settings compared to the specific fire commands. The computer will disable the weapon unless proper verification is made. Upon firing, the velocimeter provides muzzle velocity to the ballistic computer which determines the desired fuze setting. The computer then initiates an RF signal which sets the fuze to the calculated time.

### NBC Protection

Nuclear, biological, and chemical protection are provided via the M13A1 ventilated facepiece, protective clothing, and the M8 alarm system. A common filter unit supplies purified, filtered air (via hoses) to the crew members. The pressurized air system eliminates much of the breathing resistance normally associated with wearing face masks, and this system (with protective clothing) will allow operation in an open hatch mode. The M25A1 face mask permits the crew to disconnect the forced air supply and abandon the vehicle under complete NBC protection. The NBC equipment is stored on the rear of the right sponson.

### SPH Crew Requirements/Functions

A crew of three; chief of section, driver, and cannoneer is required for SPH operation. The chief of section gives and follows commands, oversees crew functioning, checks automatic weapon laying, maintains communications with the FDC and ARV as required, coordinates activities, and oversees the operation of the automated gun laying system (AGLS) to assure its proper functioning. The driver keeps the chassis and drive train in ready condition, studies local terrain, maintains the engine and APU, and assists the cannoneer during resupply operations. The cannoneer maintains and oversees operation of the autoloader, breaks propellant charges and hand loads them, and receives and stows ammunition during resupply operations.

### Ammunition Resupply Vehicle (ARV)

The ARV (figure 26) utilizes the MLRS chassis with its Cummins VTA-903 turbocharged engine, G. E. HMPT-500 hydromechanical transmission, and return roller torsion bar suspension. Smooth, high-speed travel over rough terrain is facilitated by 14-inch wheel travel and shock absorbers. Its 1-1/4-inch aluminum armor provides indirect fire survivability.

The MLRS chassis, with its tilting cab, was designed for ease of maintenance and reliability. The power pack can be replaced within 30 minutes and access panels allow for the daily maintenance checks without raising the cab. Diagnostic equipment and modular replacement parts permit rapid trouble shooting and corrective action.

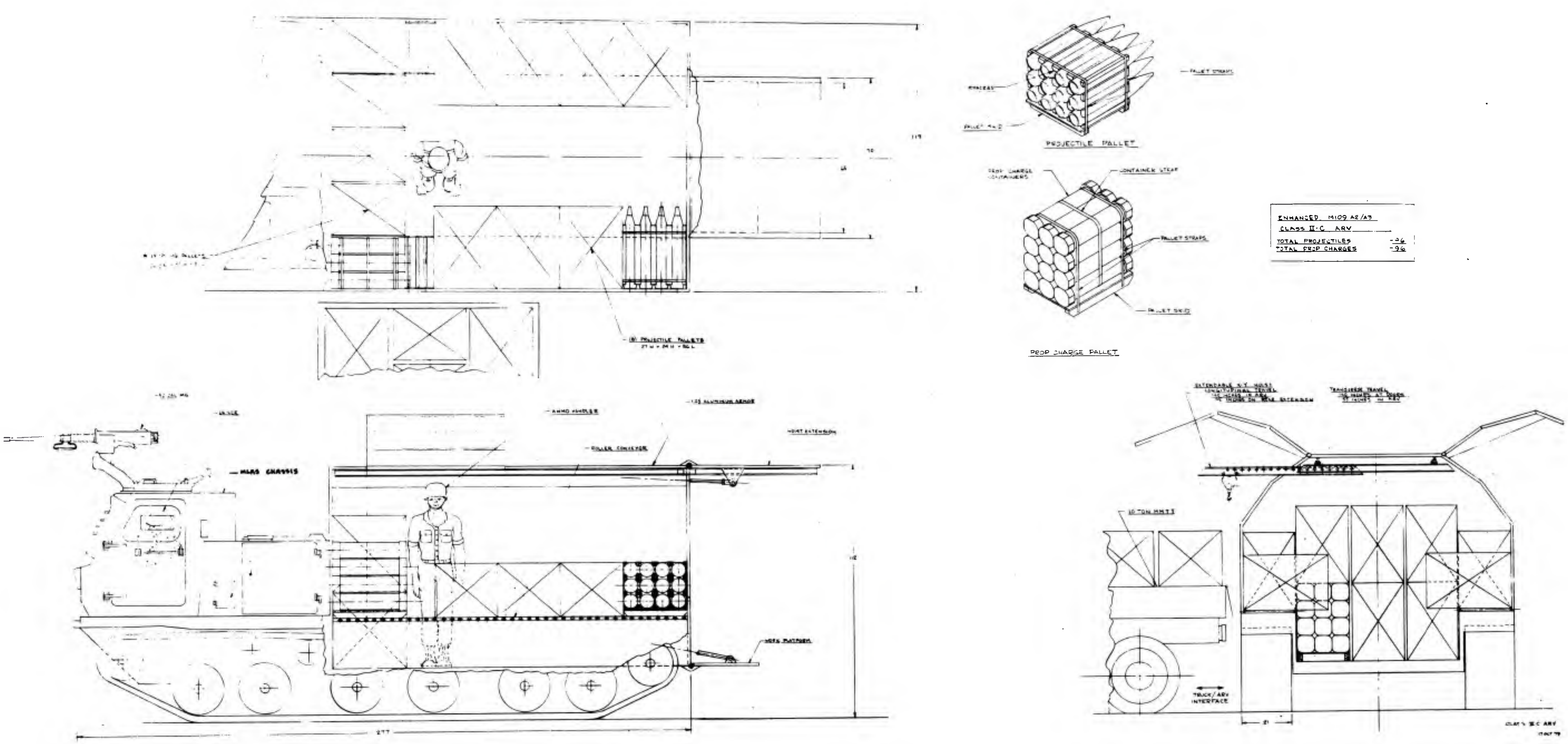



Figure 26 ARV for Enhanced M109A2 SPH (Concept IIC)

The ARV carries eight 12-projectile pallets and eight 12-propellant pallets for a total of 96 projectiles and 96 top-zone propellant charges. The propellant charges are stored across the front of the vehicle, one pallet on each sponson, three on the floor between sponsons, and a second row of three on top of these. Four projectile pallets are stowed on the rear of the two sponsons with fuzes facing the aisle. This provides an unobstructed 42-inch center aisle for a comfortable working area.

Resupply of the SPH can be accomplished either at a rendezvous point or at the battery position. The initial docking of the ARV to the SPH involves hydraulically opening the rear doors of the two vehicles and docking them back-to-back approximately five feet apart. The swing-up door on the ARV provides a trolly extension and overhead fragmentation protection.

The X-Y trolly-mounted hoist in the ARV runs on two side-mounted roof tracks with a telescoping cross member. This allows the hoist to sweep the interior area of the ARV and to reach out the back and side doors. To resupply the SPH, the trolly hoist picks up a pallet of either propellant or projectiles, carries it out the rear of the ARV and deposits it on the flip-down receiving shelf of the SPH.

The motorized roller conveyor on the SPH receiving shelf conveys ammunition into the SPH bustle area. The ammunition storage consists of 44 projectiles and 44 propellant charges. The projectile ready rack holds 32 projectiles, while a 12-round pallet is stored, as received from the ARV, in the right rear turret bustle area. The left rear of the hull is used for storage of twenty individual propellant charges. The center and left rear of the turret bustle holds two 12-canister pallets of propellant charges as received from the ARV. This storage scheme is shown in figure 26. All projectiles and propellant charges are held in place by retainers.

The SPH is loaded by first transferring the partial pallets (8 loose projectiles and 8 propellant cans) then hand stowing the projectiles in the ready rack and the propellant cans in the rear chassis. Two projectile pallets are then conveyed 10 inches into the ready rack and the projectiles are pushed the last 26 inches into the rack one by one. A propellant pallet is conveyed into the bustle area and the 12 cans are individually stacked in the rear chassis. To complete the ammunition loading, two propellant pallets and one projectile pallet are conveyed into the turret bustle area. A time study for resupplying the SPH from the ARV is given in table 13.

Table 13

ARV to SPH Resupply Time (Concept IIC)

(See Notes)

1. Docking
2. Open rear doors
3. Transfer eight rounds
4. Ready pallets P1, C1, C2
5. Convey pallet P1
6. Stow 12 projectiles
7. Convey pallet P1
8. Ready pallet P2
9. Stow 12 charges
10. Convey pallet P2
11. Ready pallets P3, C3
12. Stow 12 projectiles
13. Convey pallets P3, C3
14. Apply travel locks
15. Secure vehicle

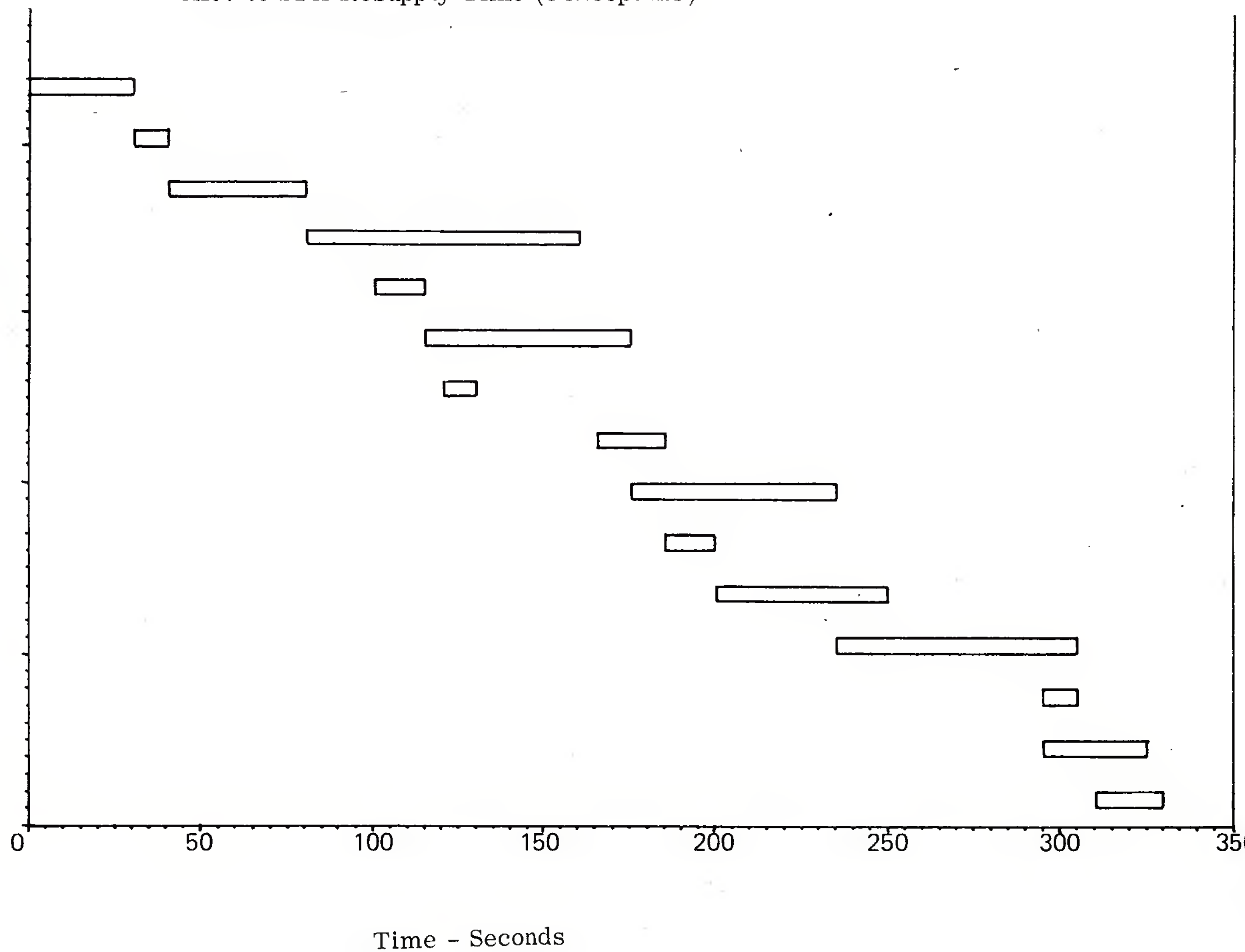


Table 13

Notes

1. 30 sec; docking
The SPH and ARV are docked back-to-back about five feet apart.

2. 10 sec; open rear doors.
The rear flip-down receiving shelf on the SPH turret and the rear swing-up trolly extension on the ARV are hydraulically opened.

3. 40 sec; transfer 8 loose rounds.
In the ARV the ammunition handler and driver work simultaneously placing projectiles and propellant charges on the SPH motorized roller conveyor. The ammunition is conveyed into the SPH turret where the SPH driver guides the projectiles into the ready rack and the cannoneer stows the charges under the turret ring.

4. 80 sec; ready first projectile pallet and first two propellant pallets.
The pallets are individually hoisted from their stowage position, trollied to and deposited on the SPH receiving shelf.

5. 15 sec; convey first projectile pallet.
The motorized roller conveyor on the SPH receiving shelf conveys the pallet into the turret and inserts the projectile ogive ten inches into the ready rack.

6. 60 sec; insert 12 projectiles into ready rack.
The driver pushes the 12 projectiles, one at a time, the last 26 inches into the ready rack, dumps the empty pallet out the side door and releases the rack's travel lock.

7. 10 sec; convey first propellant pallet.
The motorized roller conveyor on the SPH receiving shelf conveys the pallet into the turret.

8. 20 sec; ready second projectile pallet.
The pallet is hoisted from its stowage position, trollied to, and deposited on the SPH receiving shelf.

9. 60 sec; stow 12 charges.
The driver cuts the pallet bands, stows the charges under the turret ring, one at a time, and applies the travel lock.

10. 15 sec; convey second projectile pallet.
The motorized roller conveyor on the SPH receiving shelf conveys the pallet into the turret and inserts the projectile ogive 10 inches into the ready rack.

11. 50 sec; ready third projectile and propellant pallets.
The pallets are individually hoisted from their stowage position, trollied to and deposited on the SPH receiving shelf.

12. 70 sec; insert 12 projectiles into ready rack.
The driver pushes the 12 projectiles, one at a time, the last 26 inches into the ready rack, dumps the empty pallet out the side door, and secures the rack for travel.

13. 10 sec; convey third projectile and propellant pallets.
The motorized roller conveyor on the SPH receiving shelf conveys the pallets into the turret.

14. 40 sec; apply travel locks.
The three pallets in the turret bustle are secured.

15. 20 sec; secure vehicle.
The SPH and ARV rear doors are closed and the crew members return to their duty stations.

### ARV Crew Requirements/Functions

A crew of two; driver and ammunition handler, is required for ARV operation. The driver keeps the chassis and drive train in ready condition, studies local terrain, maintains the engine and APU, and assists the ammunition handler during resupply operations. The ammunition handler operates the X-Y trolly, stows ammunition, and maintains communication with the SPH.

### Resupply Truck

The ammunition supply truck (figure 27) is an all-terrain, eight-wheel-drive, drop-side, 10-ton, high mobility tactical truck (HMTT), with crane. The 360 degree crane has a 2,650 pound capacity at 16.4 feet and a lifting speed of one foot eleven inches per second. Its slewing speed is 22 degrees per second and slewing torque is 7,960 foot-pounds. The truck can either resupply the ARV or load pallets directly into the SPH.

The ARV may be resupplied through its rear door or either of its side doors. The truck may be docked to unload from either side or from its rear. The X-Y trolly of the ARV is extended over the truck's pallets, lifts the pallets 2 to 6 inches, trollies them into the ARV, and lowers them into their stowage position. The propellant charges are stowed across the front of the vehicle and the projectiles are placed on the sponsons and conveyed into stowage position. As the outer pallets are removed from the truck, the truck-mounted crane places additional pallets within the ARV's reach. The crane could also place the pallets in the ARV's doorway if preferred. See figure 28 for a view of the transfer of ammunition.

The ammunition supply truck performs a rather simple mission and, therefore, there is great interchangeability between trucks. The basic requirement is for an all-terrain flat-bed truck with a crane to hand off ammunition pallets to either the ARV or SPH. The minimum crew would be a driver/crane operator; however, a logistics log keeper is expected to accompany the truck. A time study for resupplying the ARV from the HMTT is shown in table 14.

### Battery Fire Control Vehicle

The battery fire direction center is mounted on a MLRS carrier and is depicted in figure 17. It is described on pages 213 through 219 .

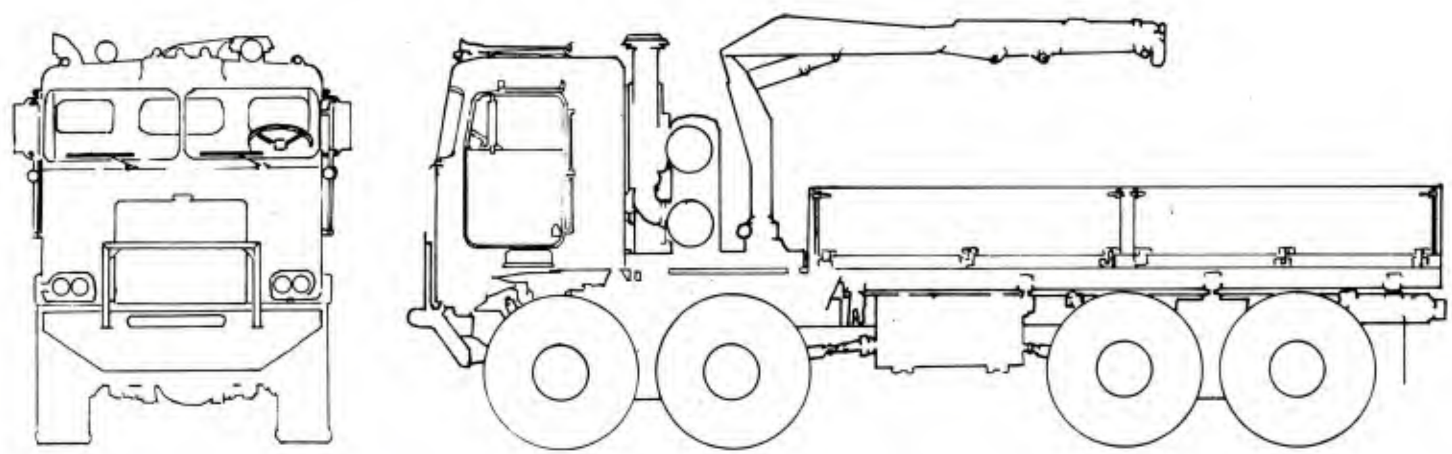


Figure 27 High Mobility Tactical Truck (HMTT) (Concept IIC)

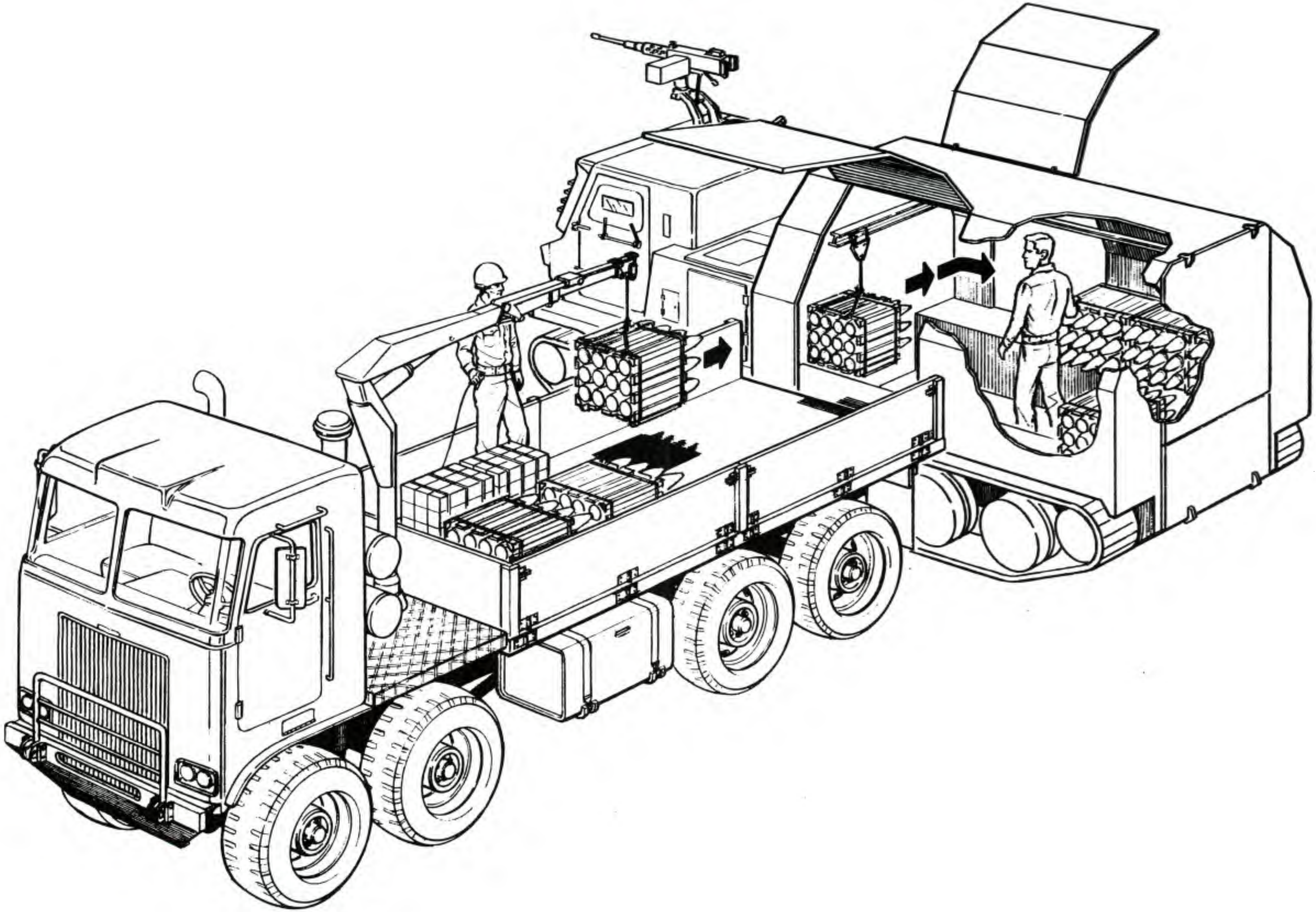


Figure 28 Transfer of Ammunition from Truck to ARV (Concept IIC)

Table 14

HMTT to ARV Resupply Time (Concept IIC)

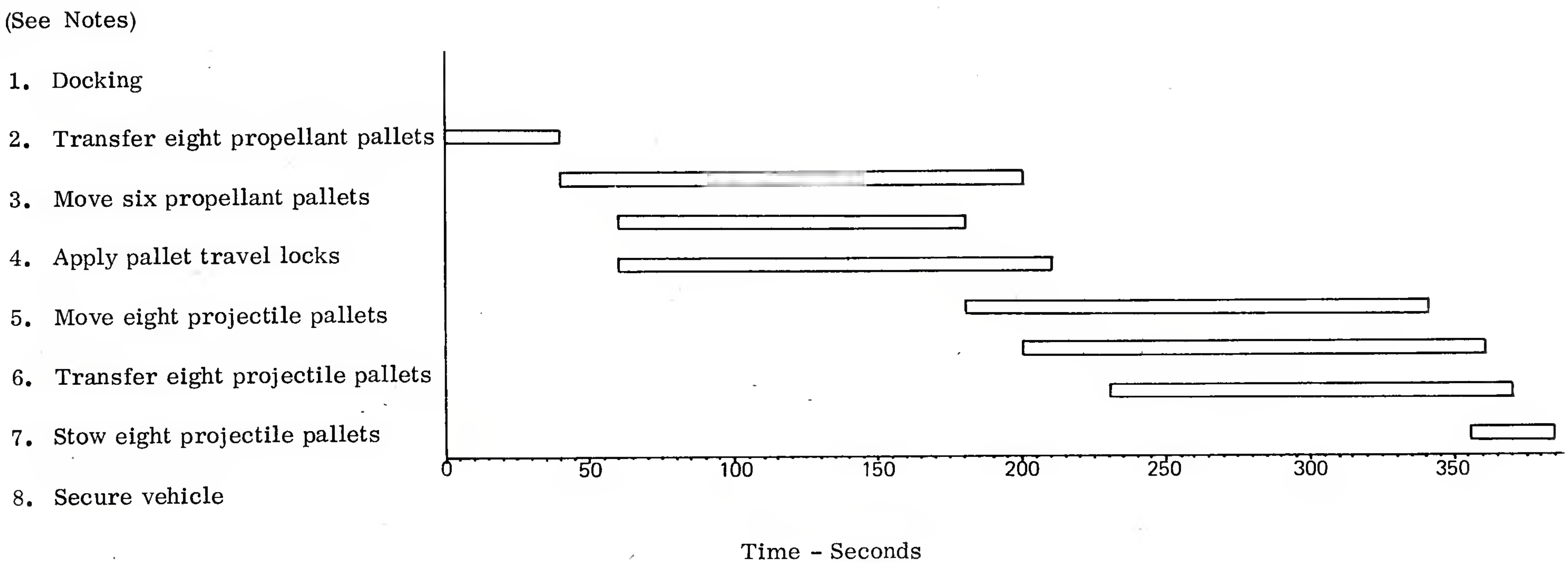


Table 14

Notes

1. 40 sec; docking.
   The ARV and HMTT are docked side-by-side 1 to 12 inches apart with the ARV's hydraulically activated doors open and the truck's drop side lowered.

2. 160 sec; transfer eight propellant pallets to ARV.
   The pallets are individually hoisted with the ARV trolly hoist off the edge of the truck, trollied into the ARV, and deposited across the front of the vehicle.

3. 120 sec; move six propellant pallets to the edge of the truck.
   As pallets are removed from the truck, the truck-mounted crane transfers additional pallets to the edge of the truck within reach of the ARV trolly hoist.

4. 150 sec; apply travel locks to propellant pallets.
   The eight propellant pallets are secured in place across the front of the ARV.

5. 160 sec; move eight projectile pallets to the edge of the truck.
   As pallets are removed from the truck, the truck-mounted crane transfers additional pallets to the edge of the truck within reach of the ARV trolly hoist.

6. 160 sec; transfer eight projectile pallets to ARV.
   The pallets are individually hoisted off the edge of the truck, trollied into the ARV, and deposited on one of the two sponsons.

7. 150 sec; stow eight projectile pallets.
   The ARV driver moves the pallets down the sponson roller conveyor to their stowage position and locks them in place.

8. 30 sec; secure vehicle.
   The truck pulls away from the ARV, the drop side is closed, the side doors closed, and the crewmen return to their duty stations.

Class III (Shoot Passive IR CLGP and Scoot)

Concept Development Philosophy

The objectives for the Class III concepts were identical to those for Class II as follows:

a. Defeat moving armored targets in region I[2].

b. Survive the counterbattery fire threat.

c. Provide ammunition on a timely basis.

In addition, the development philosophy was the same as Class II with one major exception. In order to defeat the moving armored targets, it was decided to use a passive IR CLGP as opposed to scatterable mines. Since a large number of targets are identified in a short period of time, each battery concept was required to have the following firepower characteristics:

a. Fire a burst of 12 rounds at the highest practicable firing rate.

b. Reduce the TLE to 85 meters.

c. Provide a fast response capability so that rounds could be fired immediately after the FO identifies and locates the target.

As in the Class II concepts, a "shoot and scoot" mode of operation was used as a means to survive the counterbattery fire threat, and ammunition resupply was similarly emphasized.

Given these guidelines, the following battery concepts were developed:

a. Concept IIIA consists of a casemate SPH, a companion ARV, and a battery fire control vehicle integrated with FIST.

b. Concept IIIB consists of an all new turreted SPH, a companion ARV, and a battery fire control vehicle integrated with FIST.

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[2]While the Class III concepts were optimized to defeat armored targets, an ability was retained to provide massed fire in the traditional cannon artillery role.

c. Concept IIIC consists of a maximum product improved M109 SPH, a companion ARV, and a battery fire control vehicle integrated with FIST.

Casemate SPH (Concept IIIA)

General

This concept utilizes a casemate vehcile (figure 29) firing passive IR CLGP's. The SPH and ARV are similar to those of Concept IIA. The major differences are the arrangement of ammunition within the ARV and the addition of a pair of road wheels to the SPH to improve its stability during firing. These road wheels replace the rear tension idler of Concept IIA. The chief of section's station has been relocated to the right rear of the vehicle, the power tailgate and projectile loading platform have been deleted, and the loading system has been modified to handle the longer and heavier projectile.

The physical and performance characteristics of this concept are summarized in tables 15 and 16, respectively.

Automated Loading System

This concept is designed to fire passive IR CLGP ammunition at a maximum rate of 12 rounds in 2.2 minutes. This is accomplished by the use of a fully automatic loader with a 28-round capacity magazine; 12 additional rounds can be stored in the vehicle for a total of 40 rounds.

The loading system is similar to that of Concept IIA except a flick-rammer is not used. Instead, a transfer/rammer mechanism, which incorporates a semi-rigid chain ramming device, is located just aft of the breech where the ammunition can be transferred directly into the chamber when the weapon is at 15 degrees elevation. When the transfer mechanism is lowered to the projectile pick-up station, it tilts to a horizontal position to clear the recoil path of the breech. See figure 30 for an operational view of the autoloader.

Since only two tiers of projectiles can be accommodated below the recoil path, the projectile racks are transversely inclined to increase the rack capacity and to facilitate feeding of projectiles. Propellant charges are carried in similar racks above the projectile racks. To provide the clearance required for the gun's recoiling components, the right and left banks of the propellant charge racks are spaced further apart than the projectile racks. During the loading procedure, a ramp is used to bridge the gap between the propellant racks to facilitate moving the propellant charge from the rack to the transfer/rammer mechanism. (The propellant charges must be pre-adjusted manually prior to firing, since no automated charge cutter is included in the system.)

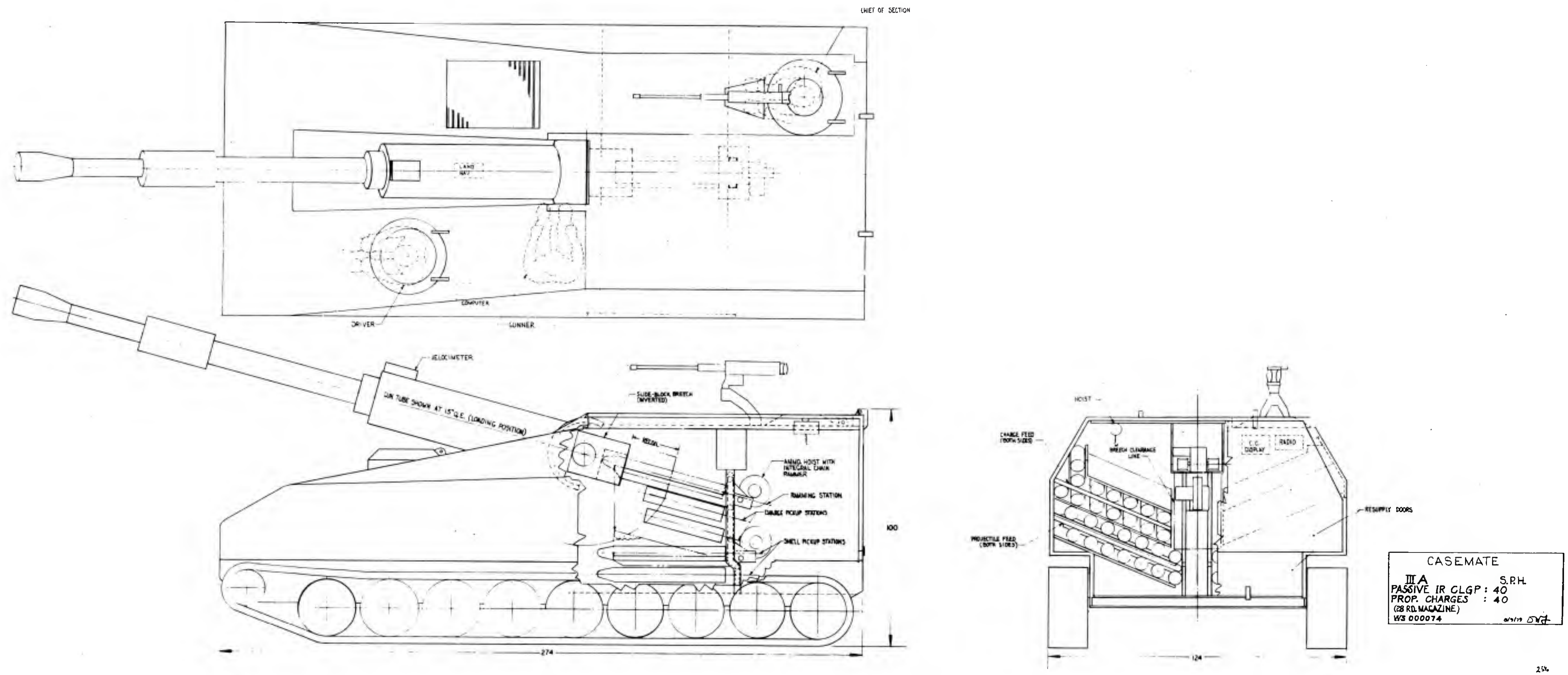



Figure 29 Casemate SPH (Concept IIIA)

Table 15

Casemate Concept IIIA - Physical Characteristics

| General Data | SPH | ARV | Ammo Truck |
|---|---|---|---|
| Weight | | | |
| Combat loaded (lb) | 69,000 | 59,000 | 48,840 |
| Net weight (lb) | 57,000 | 30,000 | 27,800 |
| Fuel capacity (gal) | 318 | 318 | 100 |
| Personnel | 3 | 3 | 2 |
| Dimensions | | | |
| Length (in) | 274 | 274 | 349 |
| Width (in) | 124 | 124 | 96 |
| Height (in) | 98 | 90 | 108 |
| Ground clearance (in) | 17 | 17 | 17 |
| Wheel size (in) | 24 | 24 | 24X20.5R |
| Track width (in) | 16 | 16 | --- |
| **Firepower** | | | |
| Armament | 155mm cannon .50-cal mg | .50-cal mg | --- |
| Elevation/depression (deg) | +75/0 | --- | --- |
| On-board traverse (deg) | + 5 | --- | --- |
| Breech type | Slide block | --- | --- |
| Number of rounds carried | 40 | 96 | 96 |
| Family of projectiles | Passive IR CLGP/HE/ICM | Passive IR CLGP/HE/ICM | Passive IR CLGP/HE/ICM |
| Type of ammo handling | Auto load/auto ram | Crane | Crane |

Table 15

Casemate Concept IIIA - Physical Characteristics (Cont'd)

| | SPH | ARV | Ammo Truck |
|---|---|---|---|
| **Mobility** | | | |
| Suspension | Full width torsion bar | Full width torsion bar | Walking beam |
| Lockout on suspension | Yes | --- | --- |
| Automotive | | | |
| Engine | Cummins VTA-903 | Cummins VTA-903 | 440 diesel |
| Transmission | AMX-1000 | AMX-1000 | Hydrokinetic automatic |
| **Survivability** | | | |
| Armor protection (in) | Aluminum 1.25 (same as M109) | Aluminum 1.25 (cab only) | |
| NBC protection | Hybrid-(ventilated facepiece) (positive pressure) | Hybrid-(ventilated facepiece) (positive pressure) | Ventilated facepiece |

Table 16

Casemate Concept IIIA - Performance Characteristics

| | SPH | ARV | Ammo Truck | Battery |
|---|---|---|---|---|
| **Firepower** | | | | |
| Min/max range (km) | | | | |
| Passive IR CLGP | 8/22 | | | |
| HE (RAP) | 8/22 (30) | ---- | ---- | ---- |
| ICM (RAP) | 8/22 (30) | ---- | ---- | ---- |
| Shoot and scoot response | | | | |
| Firing rate (passive IR CLGP) | 12 rds/2.2 min | ---- | ---- | ---- |
| .5 to 2 km relocation time (min) | 15 | ---- | ---- | ---- |
| Max weapon missions/hour | 3 | ---- | ---- | ---- |
| TLE (m) | 85 | ---- | ---- | ---- |
| Battery ammunition usage (rds/day) | | | | |
| 17 target/hour | 4,896 | ---- | ---- | ---- |
| Max firing rate | 6,912 | ---- | ---- | ---- |
| **Ammunition Supply** | | | | |
| Basic load (rds) | 40X8=320 + | 120X8=960 + | 96X6=576 = | 1,856 |
| Ammunition resupply (min) | 19.2 | 13.5 | | |
| Battery resupply rate (17 trucks at battalion) | | | | |
| 40% ASP/60% ATP (rds/day) | | | | 3,712 |
| 100% ATP (rds/day) | | | | 6,528 |

Table 16

Casemate Concept IIIA - Performance Characteristics (Cont'd)

| | SPH | ARV | Ammo Truck | Battery |
|---|---|---|---|---|
| **Mobility** | | | | |
| Cruising range (km) | 500 | 500 | 600 | ---- |
| Hp/ton | 16 | 18.6 | 17.3 | ---- |
| Max speed-primary roads (kph) | 60 | 60 | 89 | ---- |
| Ground pressure (psi) | 10.4 | 10 | ---- | ---- |
| Max grade (%) | 60 | 60 | .60 | ---- |
| Verticle obstacle (m) | 0.53 | 0.53 | 0.4 | |

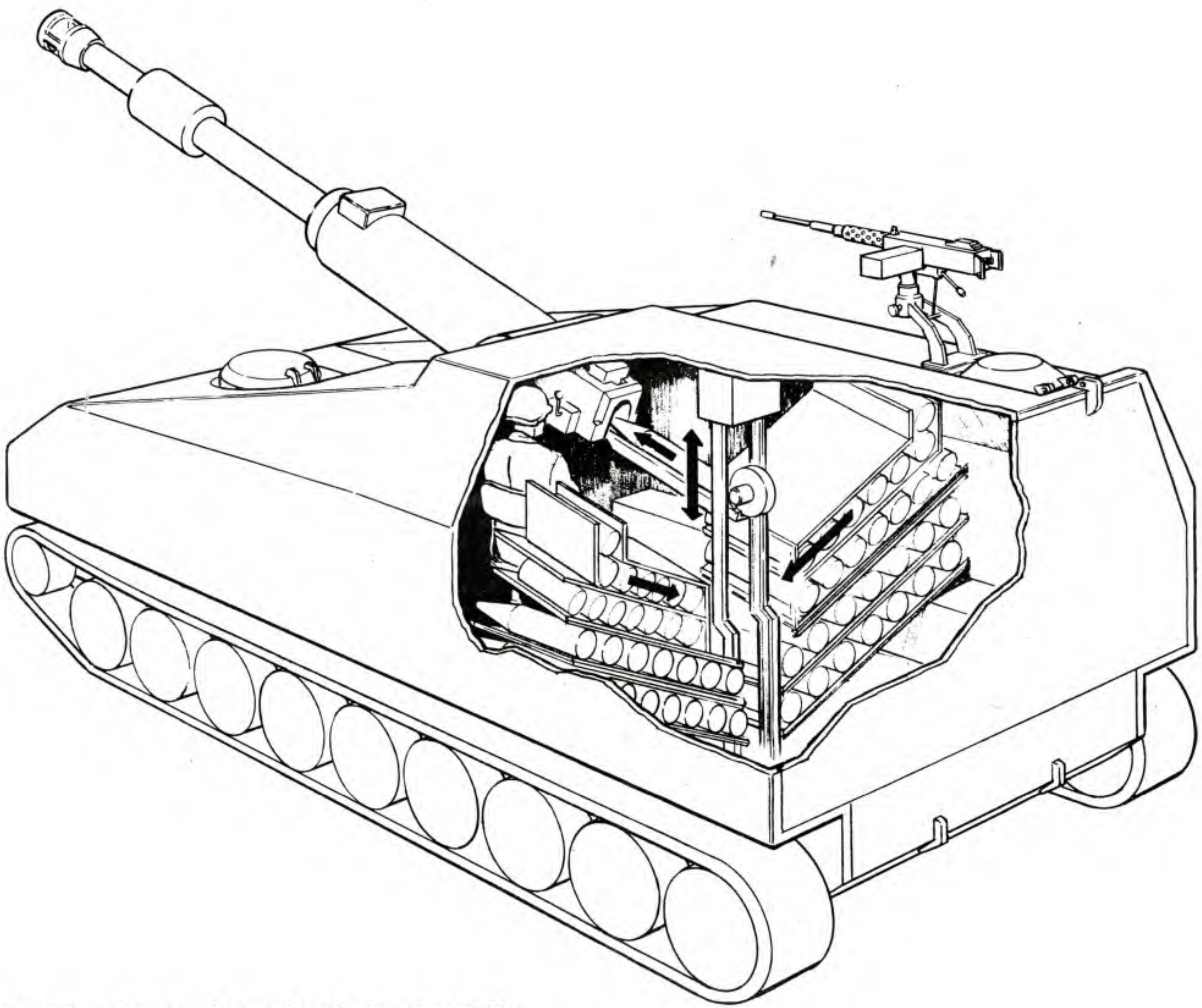


Figure 30 Operational View of Autoloader (Concept IIIA)

The projectiles and charges are loaded in independent operations. The projectile is placed into the transfer/rammer mechanism in a horizontal plane. As the projectile's vertical loading position is approached by the transfer/rammer mechanism, a 15-degree change in pitch angle is made and proper alignment with the tube is achieved. The projectile is then rammed into the chamber and the charge loading cycle is initiated. The charge loading cycle differs from the projectile loading cycle as follows: The ramming velocity is lower, the charges are stowed in a 15-degree inclined position, and a ramp is required to bridge the gap between the stowage tiers and the transfer/rammer mechanism.

### Fire Control and Communication Equipment

The heart of the on-carriage fire control system is the ballistic computer. It receives weapons location data from a land navigation subsystem, gun pitch, roll, and direction from gun sensors, meterological data from MET MESSAGE, propellant charge temperature from the propellant charge monitor, and the fire mission from the battery FDC. Through a digital message device, the computer instructs the autoloader as to the selected propellant charge. The computer selects the desired projectile from the ready rack. After the gun has been loaded and automatically laid to the calculated azimuth and elevation, the chief of section display indicates the actual weapon settings compared to the specific fire commands. The computer will disable the weapon unless proper verification is made. Location of the fire control computer, velocimeter, land navigation system, gun sensor, fuze setter, radio, chief of section display, and power package are shown in the SPH layout figure 8.

### NBC Protection

A ventilated facepiece is employed. A positive pressure system is also utilized. Using a hybrid system, the SPH can fire 40 rounds; 28 rounds can be fired automatically from the ready rack and 12 can be fired manually before it becomes necessary to resupply. Resupply would take place in a prearranged "clean" area an appropriate distance from any contaminated area.

### SPH Crew Requirements/Functions:

Driver - Operates and maintains vehicle. Also assists with ammunition handling.

Chief of section - Responsible for communication and coordination of activities. Also uses .50-caliber machinegun.

Gunner - Operates fire control equipment and handles ammunition.

## Ammunition Resupply Vehicle (ARV)

The ARV chassis and bed are similar to Concept IIA except, for simplicity, the gantry crane has been replaced by a conventional pivot-mounted extension crane. See figure 31 for the ARV layout. The ammunition arrangement has been revised because of the increased length of the projectiles. Sixteen pallets, each containing six CLGP's in a 1 by 6 matrix, are stowed on the cargo bed with room for four additional pallets below the bed between the sponsons. If the extra pallets are loaded, they may be removed with the ARV crane by lifting each pallet through the doors in the floor. If desired, the total number of rounds carried may be increased by loading a mixture of CLGP and conventional ammunition. The propellant pallets, each containing 12 complete charges (for a total of 96), are stacked two high on one side of the vehicle bed. In an emergency, four additional charge pallets may be added by stacking them three high. This arrangement permits loading the ARV by fork lift and/or by the on-board crane. The ARV crane also is used in the SPH loading sequence to position the pallets on the indexing fixtures which cants and aligns the pallet with the projectile ready rack.

The resupply procedure requires the ARV to be in a back-to-back configuration with the SPH. This position is necessary to enable the pivot-mounted crane to place the projectile pallet on a loading fixture which aligns the center lines of the projectiles with the center lines of the ready rack stowage positions. Once the projectile pallet is in position, the projectiles are pushed through the shipping tubes into the ready rack. See figure 32 . This process is repeated three additional times. The four remaining projectiles are manually loaded as are all propellant charges. In addition to the ready rack stowed rounds, there is room to the left of the chief of section to stow two additional pallets (12 each) of projectiles and propellant charges. These rounds may be loaded by using the hoist and rail provided in the SPH. A time study for resupplying the SPH from the ARV is shown in table 17.

## Resupply Truck

The ammunition supply truck (same as Concept IIA) is capable of carrying 96 projectiles and 96 propellant charges. The method for resupplying the ARV consists of the following steps:

1. Drive truck alongside the ARV.

2. Use both cranes (ARV & truck) to transfer the pallets onto the ARV.

3. Strap down projectiles and propellant charges.

4. Stow cranes on both vehicles.

The above procedure requires 5 men for economy of operation. A concentrated effort must be made to perform the operation with the cranes operating concurrently. A time study for resupplying the ARV from the truck is shown in table 18.

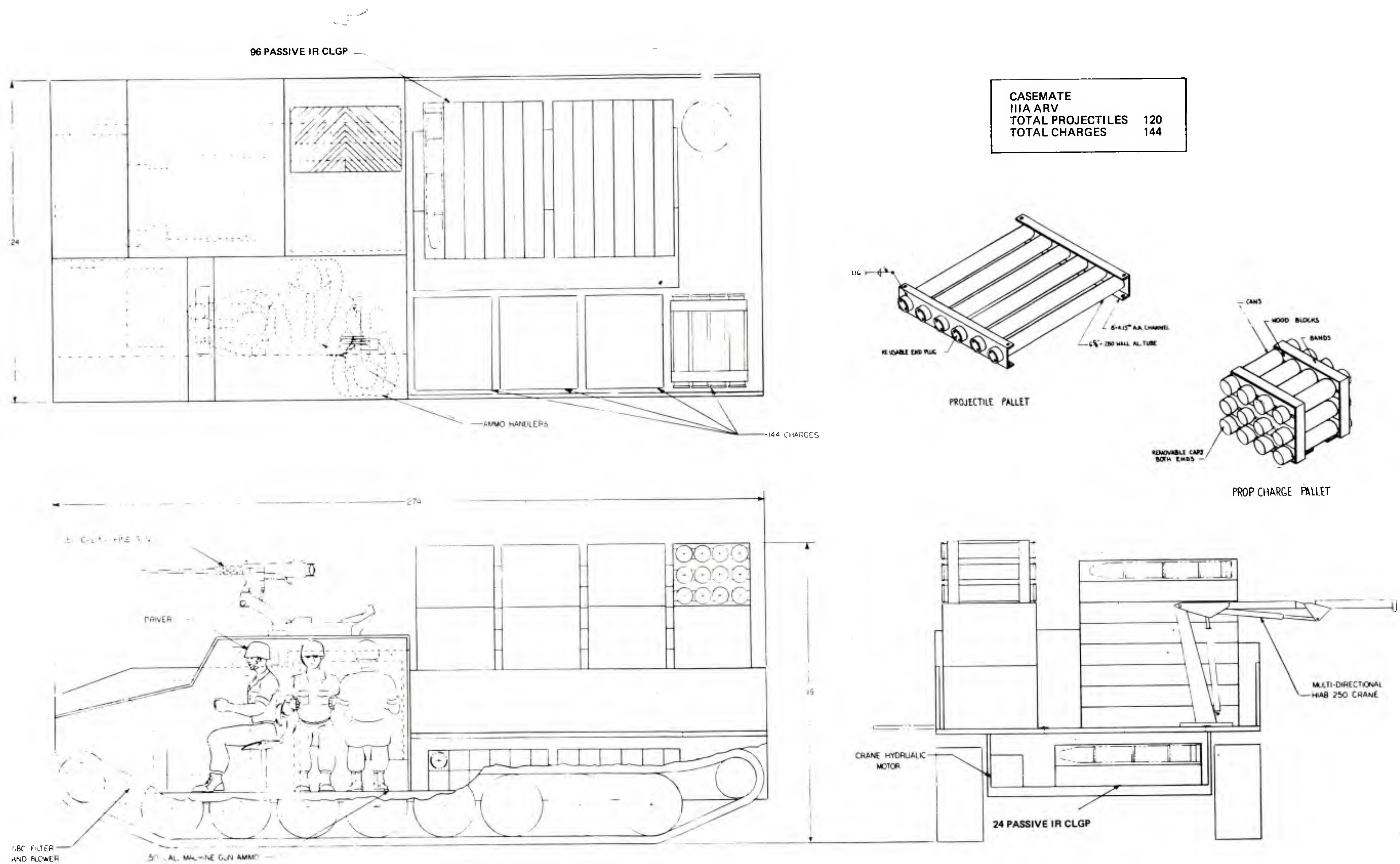



Figure 31 Casemate ARV (Concept IIIA)

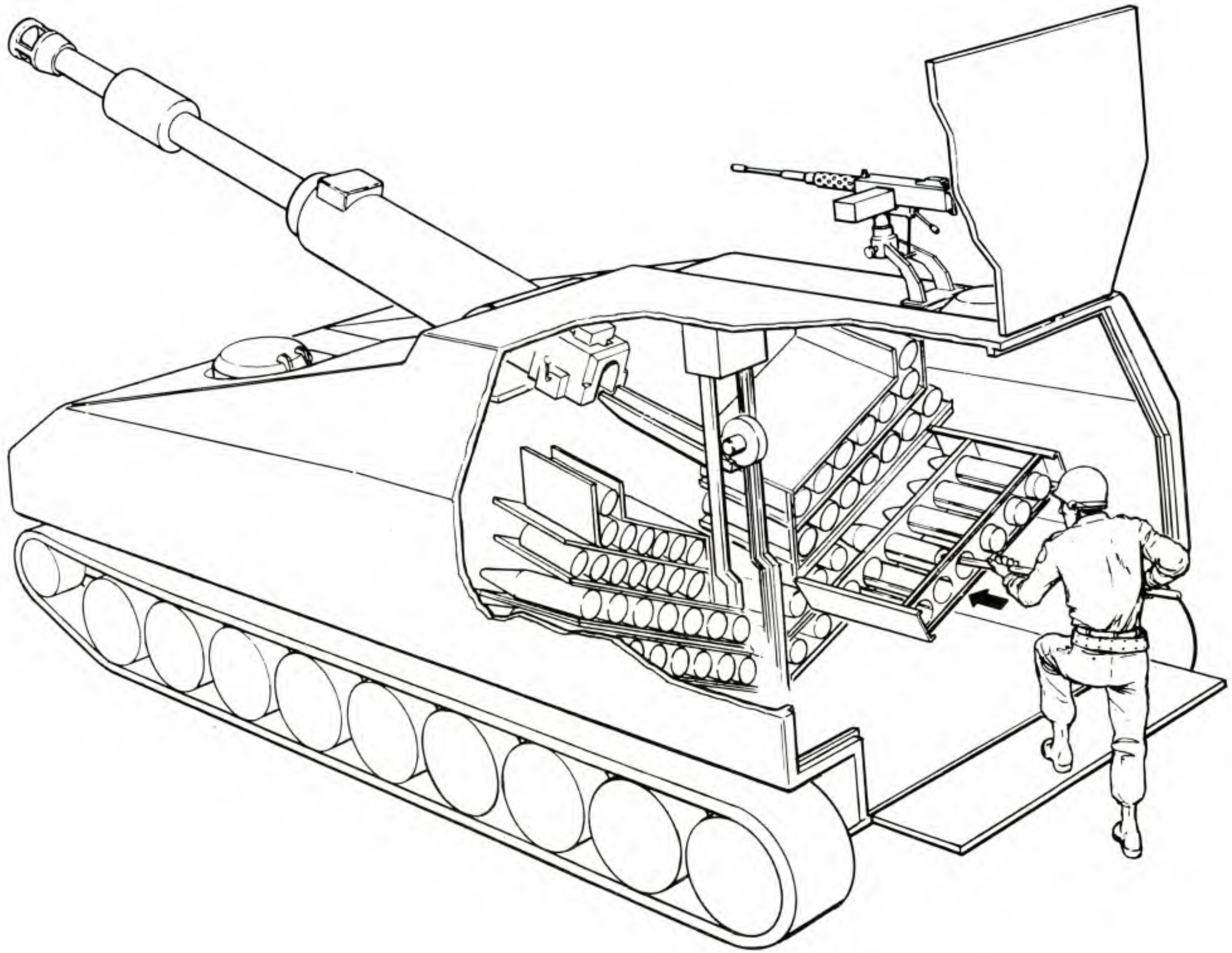


Figure 32 Push Loading Projectile from Pallet into Ready Rack (Concept IIIA)

Table 17

ARV to SPH Resupply Time (Concept IIIA)

| | | Time (sec) | Elapsed time (sec) |
|---|---|---|---|
| 1. | Dock ARV back-to-back with SPH; open doors. | 45 | 45 |
| 2. | Hoist projectile pallet with crane and position in SPH on indexing fixture. (Two men guide pallet into position). | 60 | 105 |
| 3. | Manually push six rounds into the ready rack; discard pallet. | 30 | 135 |
| 4. | Hoist propellant charge pallet and place in SPH on side opposite the projectile pallet. | 60 | 195 |
| 5. | Manually load 12 charges into ready rack. | 60 | 255 |
| 6. | Repeat steps 2 thru 5. (24 charges & 12 projectiles now loaded) | 210 | 465 |
| 7. | Repeat steps 2 & 3. | 90 | 555 |
| 8. | Repeat steps 2 & 3. | 90 | 645 |
| 9. | Manually transfer & load four projectiles and four charges. | 240 | 885 |
| | Time for 28 rounds | = | 14.7 min. |
| 10. | Hoist two pallets of projectiles and two pallets of charges into the SPH. Strap down. | 240 | 240 |
| 11. | Inspect & close doors. | 30 | 270 |
| | | | 4.5 min. |
| | Total time. (Using available space for two additional pallets) | | 19.2 min. |

Table 18

Truck to ARV Resupply Time (Concept IIA)

| | | Time (sec) | Elapsed time (sec) |
|---|---|---|---|
| 1. | Dock truck parallel with ARV. | 30 | 30 |
| 2. | Using ARV on-board crane, pick up and transfer two propellant charge pallets from rear of truck; simultaneously using truck on-board crane transfer the two foremost charge pallets to far side of ARV. | 90 | 120 |
| 3. | Use ARV crane to transfer two additional charge pallets. | 90 | 210 |
| 4. | Use ARV crane to transfer two projectile pallets to aft section of ARV. Simultaneously use the truck crane to position two projectiles in forward position | 90 | 300 |
| 5. | Use ARV crane to transfer two projectile pallets to aft of ARV while truck crane transfers the two remaining charge pallets to the ARV. | 90 | 390 |
| 6. | Use ARV crane to transfer two projectile pallets to aft of ARV while truck crane transfers two projectile pallets to ARV foreward stack. | 90 | 480 |
| 7. | Repeat step 6. | 90 | 570 |
| 8. | Use truck crane to transfer two projectile pallets to ARV foreward stack. | 90 | 660 |
| 9. | Stow ARV & truck cranes. | 30 | 690 |
| 10. | Strap down projectiles and charges and drive away. | 120 | 810 |
| | | Total time | 13.5 min |

Note: Time is not included for loading four pallets of projectiles in space below ARV deck. No charges are on board for these projectiles.

### Battery Fire Control Vehicle

The battery fire direction center is mounted on a MLRS carrier and is depicted in figure 17. It is described on pages 213 through 219 .

## New Turreted SPH (Concept IIIB)

### General

The overall envelope of the Class III turreted SPH (figure 33) is approximately the same as that outlined for the Class II turreted SPH. There are differences in ready rack design, the automated loading concept, and ammunition arrangement. These are discussed in subsequent paragraphs. Combat weight is estimated to be 68,000 pounds, which is 2,000 pounds lighter than the Class II vehicle. This is the result of improvements in ammunition handling in one instance, and a reduction in ammunition storage capability (space constraints), in another.

The physical and performance characteristics of this concept are listed in tables 19 and 20, respectively.

### Turret/Armament

The primary weapon system is the same as that used with Concept IIB.

### Automated Loading System

Instead of using drums as in Concept IIB, 20 passive IR CLGP are stored in columns at the rear of the turret on both sides of the breech block as depicted in figure 33 . A transfer tray moves laterally and horizontally under the columns of rounds. Indexed stops are provided to bring the transfer tray in direct alignment with a selected column of rounds for receiving the CLGP which is held directly above the tray. See figure 34 for an operational view of the autoloader.

With the aid of gravity and the kinematic relationships of the mechanical parts (slide blocks, pawls of figure 35), the projectile held directly above the tray can be quickly released onto the tray while each of the remaining column elements (rounds) slides or drops gently to the cell directly below which is made available by the simultaneous downward motions of the column elements. Figure 35 , callouts 2A through 2E, shows a complete cycle of the slide block mechanisms for lowering a round from its original position to a cell which is located one caliber beneath it.

Upon receiving the projectile, the transfer tray moves laterally to bring the projectile in direct alignment with the breech block at zero degree elevation. A chain drive mounted on the tray is used to push the projectile into the breech block. A flick/rammer mechanism is attached to the front of the transfer tray to ensure that

Table 19

New Turreted Concept IIIB - Physical Characteristics

| General Data | SPH | ARV | Ammo Truck |
|---|---|---|---|
| Weight | | | |
| Combat loaded (lb) | 68,000 | 61,000 | 36,680 |
| Net weight (lb) | 55,000 | 47,000 | 21,680 |
| Fuel capacity (gal) | 220 | 220 | 78 |
| Personnel | 4 | 3 | 2 |
| Dimensions | | | |
| Length (in) | 251 | 251 | 317 |
| Width (in) | 123 | 123 | 92 3/4 |
| Height (in) | 111 | 114 | 85 1/2 |
| Ground clearance (in) | 18 | 18 | 10 1/2 |
| Wheel size (in) | 24 | 24 | 11RX20 |
| Track width (in) | 21 | 21 | 6-wheel drive |
| **Firepower** | | | |
| Armament | 155mm cannon, .50-cal mg | .50-cal mg | |
| Elevation/depression (deg) | 65/0 | | |
| On-board traverse (deg) | 360 | | |
| Breech type | Slide block | | |
| Number of rounds carried | 20 | 52 | 66 |
| Family of projectiles | Passive IR CLGP/HE/ICM | Passive IR CLGP/HE/ICM | Passive IR CLGP/HE/ICM |
| Type of ammo handling | Auto load projeciles/manually load prop charges | Power assist (hoist, conveyor) | Power assist (crane) |

Table 19

New Turreted Concept IIIB - Physical Characteristics (Cont'd)

| | SPH | ARV | Ammo Truck |
|---|---|---|---|
| **Mobility** | | | |
| Suspension | Full width torsion bars | Full width torsion bars | Tapered leaf |
| Lockout on suspension | Yes | No | No |
| Automotive | | | |
| Engine | Cummins VTA-903 | Cummins VTA-903 | Cummins NHC-250 |
| Transmission | AMX-1000 | AMX-1000 | 5-speed manual synchromesh |
| **Survivability** | | | |
| Armor protection (in) | Similar to M109 | Similar to M109 | |
| NBC protection | Hybrid | Hybrid | Ventilated facepiece |

Table 20

New Turreted Concept IIIB - Performance Characteristics

| | SPH | | ARV | | Ammo Truck | | Battery |
|---|---|---|---|---|---|---|---|
| **Firepower** | | | | | | | |
| Min/max range (km) | | | | | | | |
| Passive IR CLGP | 8-22 | | | | | | |
| HE (RAP) | 8-22 (30) | | | | | | |
| ICM (RAP) | 8-22 (30) | | | | | | |
| Shoot and scoot response | | | | | | | |
| Firing rate (passive IR CLGP) | 12 rds/2 min | | | | | | |
| .5 to 2 km relocation time (min) | 15 | | | | | | |
| Max weapon missions/hour | 3 | | | | | | |
| TLE (m) | 85 | | | | | | |
| Battery ammunition usage (rds/day) | | | | | | | |
| 17 targets/hour | 4,896 | | | | | | |
| Max firing rate | 6,912 | | | | | | |
| **Ammunition Supply** | | | | | | | |
| Basic load (rds) | 8X20 | + | 8X52 | + | 6X66 | = | 972 |
| Ammunition resupply (min) | 7 | | 10 | | | | |
| Battery resupply rate (17 trucks at battalion) | | | | | | | |
| 40% ASP/60% ATP (rds/day) | | | | | | | 2,552 |
| 100% ATP (rds/day) | | | | | | | 4,488 |

Table 20

New Turreted Concept IIIB - Performance Characteristics (Cont'd)

| | SPH | ARV | Ammo Truck | Battery |
|---|---|---|---|---|
| Mobility | | | | |
| Cruising range (km) | 478 | 524 | 460 | |
| Hp/ton | 18 | 20 | 13.9 | |
| Max speed-primary roads (kph) | 62 | 68 | 70 | |
| Ground pressure (psi) | 9.3 | 8.3 | 23 | |
| Max grade (%) | 60 | 60 | 60 | |
| Verticle obstacle (m) | 0.64 | 0.64 | ---- | |

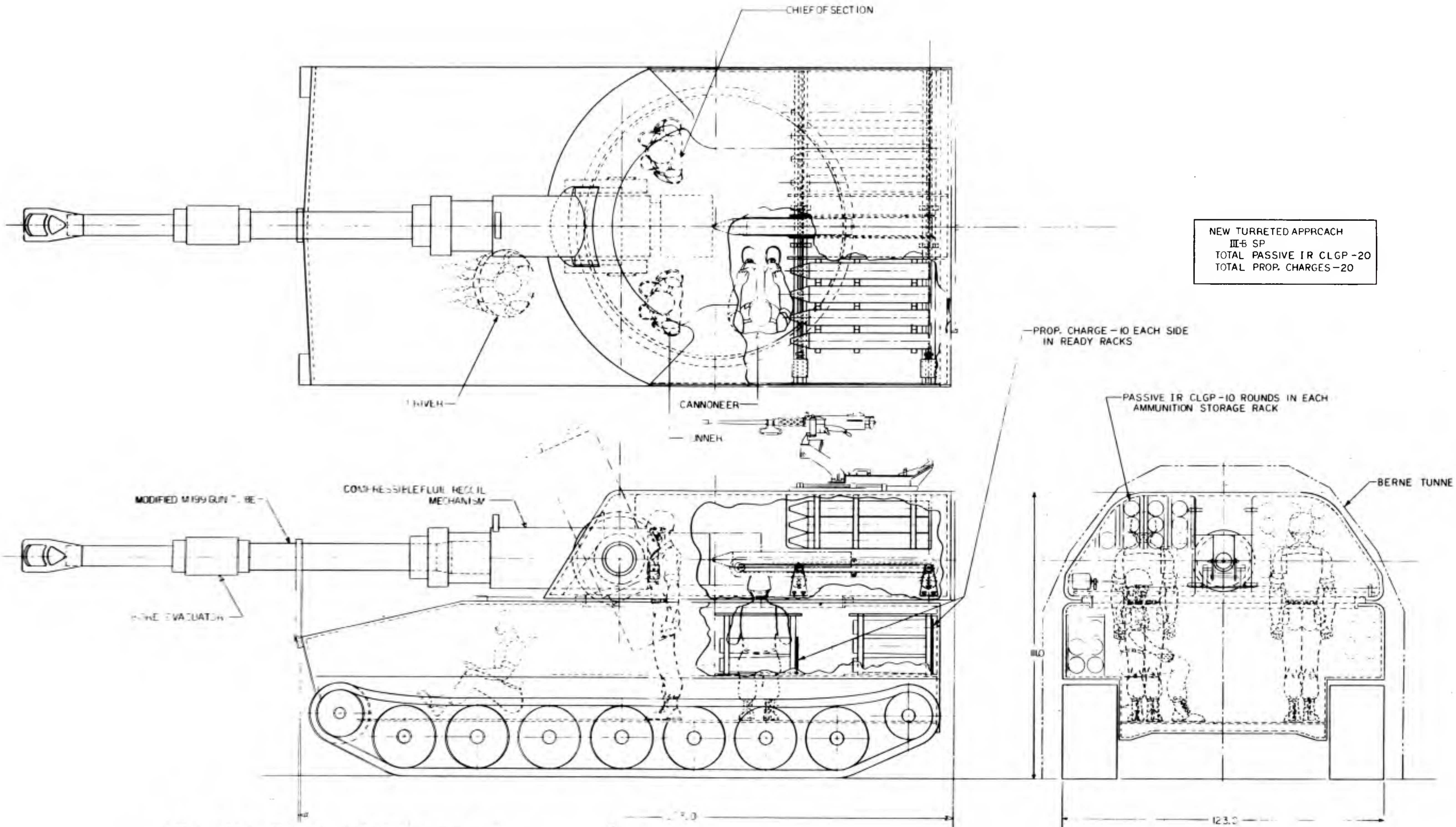



Figure 33 New Turreted SPH (Concept IIIB)

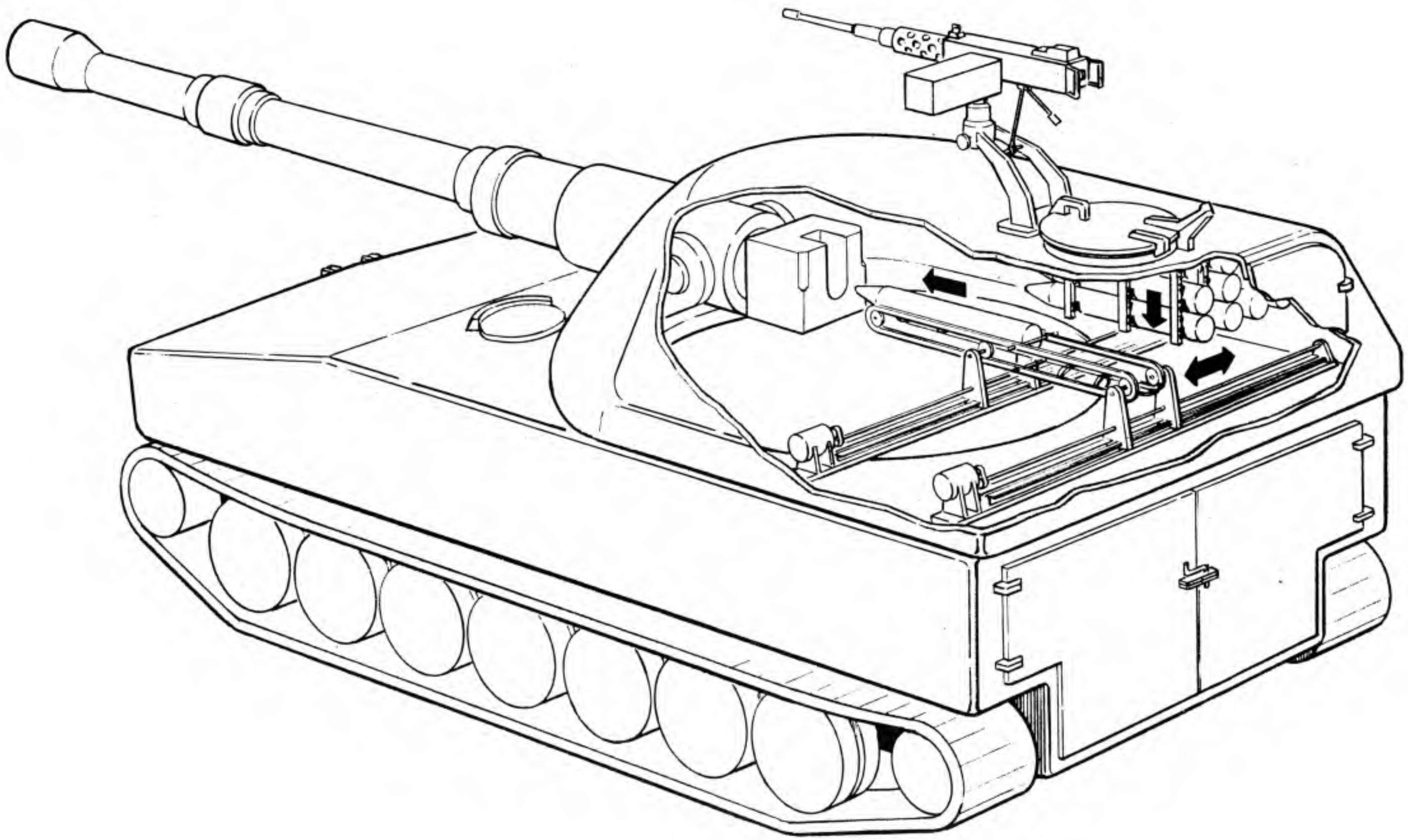


Figure 34 Operational View of Autoloader (Concept IIIB)

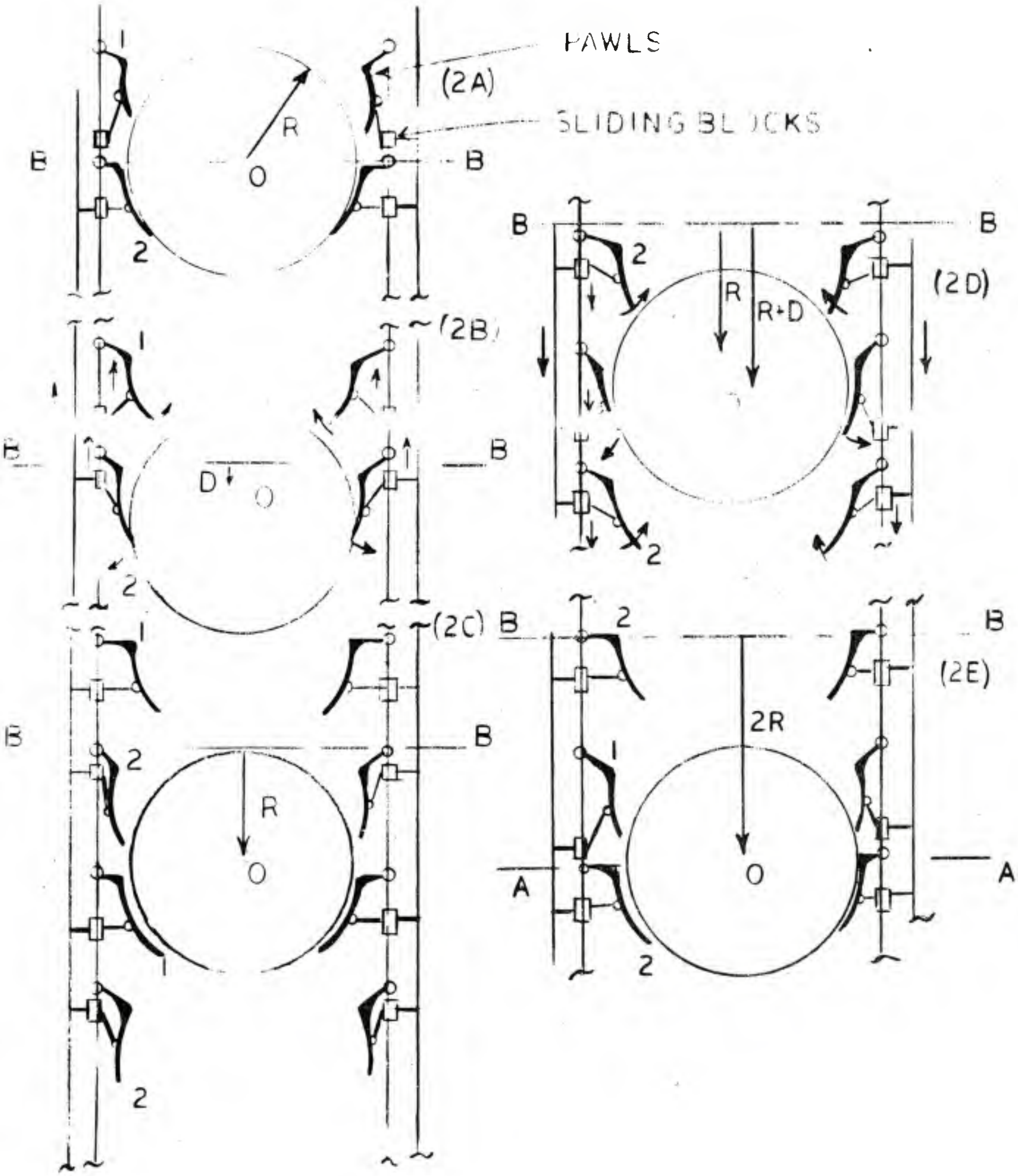



Figure 35 Slide-Block Mechanism (Concept IIIB)

the projectile and propellant charge that follows will seat properly, permitting the breech block to be closed.

Transfer, loading, and ramming of shorter projectiles, such as HE and ICM rounds, poses no problem for this concept. The mechanism will operate as before. Some additional spacers will be required, however, to store and secure the shorter projectiles in the oversize ready rack.

Propellant charges are stored on the sponsons. They are preset for the range desired. The propellant charge is picked up manually and placed on the transfer tray for ramming after the CLGP has been loaded into the breech block.

Fire Control and Communication Equipment

The heart of the on-board fire control system is the ballistic computer. It receives weapon position data from a land navigation subsystem, gun pitch, roll, and direction from gun sensors, meterological data from MET MESSAGE, propellant charge temperature from the propellant charge monitor, and the fire mission from the battery FDC. Through a digital message device, the computer activates the automated loading system for selection of propellant charge and desired projectile from the ready rack. After the gun has been loaded and automatically laid to the calculated azimuth and elevation, the chief of section display indicates the actual weapon settings compared to the specific fire commands. The computer will disable firing unless proper verification is made. Arrangement of the fire control computer, velocimeter, land navigation system, gun sensors, fuze setter, radio, chief of section display, and power package are as shown in the Concept IIB layout (figure 19).

NBC Protection

A ventilated facepiece is employed. A positive pressure system may be utilized. Using a hybrid system, the SPH can fire 20 rounds before it becomes necessary to resupply. Resupply would take place in a prearranged "clean" area an appropriate distance from any contaminated area.

SPH Crew Requirements/Functions:

Driver - Operates and maintains vehicle; assits with ammunition handling.

Chief of section - In charge of communication, coordination, etc.

Gunner - Operates FC equipment and controls automated feeding mechanism which loads CLGP from ready rack into breech block.

Cannoneer - Presets propellant charge; picks up charge and places it onto transfer tray after CLGP has been loaded; pushes "button" ramming charge into breech block.

Ammunition Resupply Vehicle (ARV)

The automotive aspect of the vehicle, armor material/thickness, and NBC protection is the same as Concept IIB ARV. The overall envelope of the vehicle is shown in figure 36. Six CLGP pallets (of six projectiles each) are stored in the ARV and 16 CLGP's (in containers) are placed and secured on top of the stacked pallets. Also on board are sufficient propellant charges (in containers) to fire all the projectiles. If desired, the total number of rounds carried may be increased by loading a mixture of CLGP and conventional ammunition. Due to space constraints in handling the oblong CLGP pallets, an off-set rear door is required to prevent interference. No side door is used with this design concept. The rear door is in two sections. The upper section, hinged at the roof, provides ballistic protection during the loading operation. The lower section, in the open position, is actually a hydraulic lift gate which provides height adjustment for receiving ammunition from the supply truck and for replenishing the ready rack.

The ARV is equipped with an extendable gantry (similar to that in the Concept IIB ARV) to receive pallets from the lift gate, and a dismountable conveyor for handling ammunition between the ARV and SPH. By docking the ARV to the SPH (back-to-back) and opening the rear doors of the vehicles, the conveyor can be quickly mounted on the lift gate of the ARV. A ready rack of 20 CLGP is replenished with the aid of the cantilever mounted conveyor in a manner similar to that described for Concept IIB. The conveyor is used as a platform for ammo preparation. While the ready rack is being replenished, propellant charges are loaded manually from the ARV to the SPH chassis through its rear door. A time study for resupplying the SPH from the ARV is presented in table 21.

Resupply Truck

Resupply of the ARV is accomplished at a rendezvous point where an M813 supply truck can be docked to unload ammunition from either side or the rear of the truck onto the tailgate of the ARV. Since there is no side door in this concept, replenishment is through the offset rear door. Six CLGP pallets can be stored away quickly by using the gantry crane mounted on the ARV. The remaining three pallets are broken down and the projectiles are picked up manually and placed on top of the stacked pallets. Propellant charge pallets are broken down on the tailgate and each unit is picked up and stored in its proper location in the ARV. Ammunition resupply time is estimated to be approximately 10 minutes (table 22).

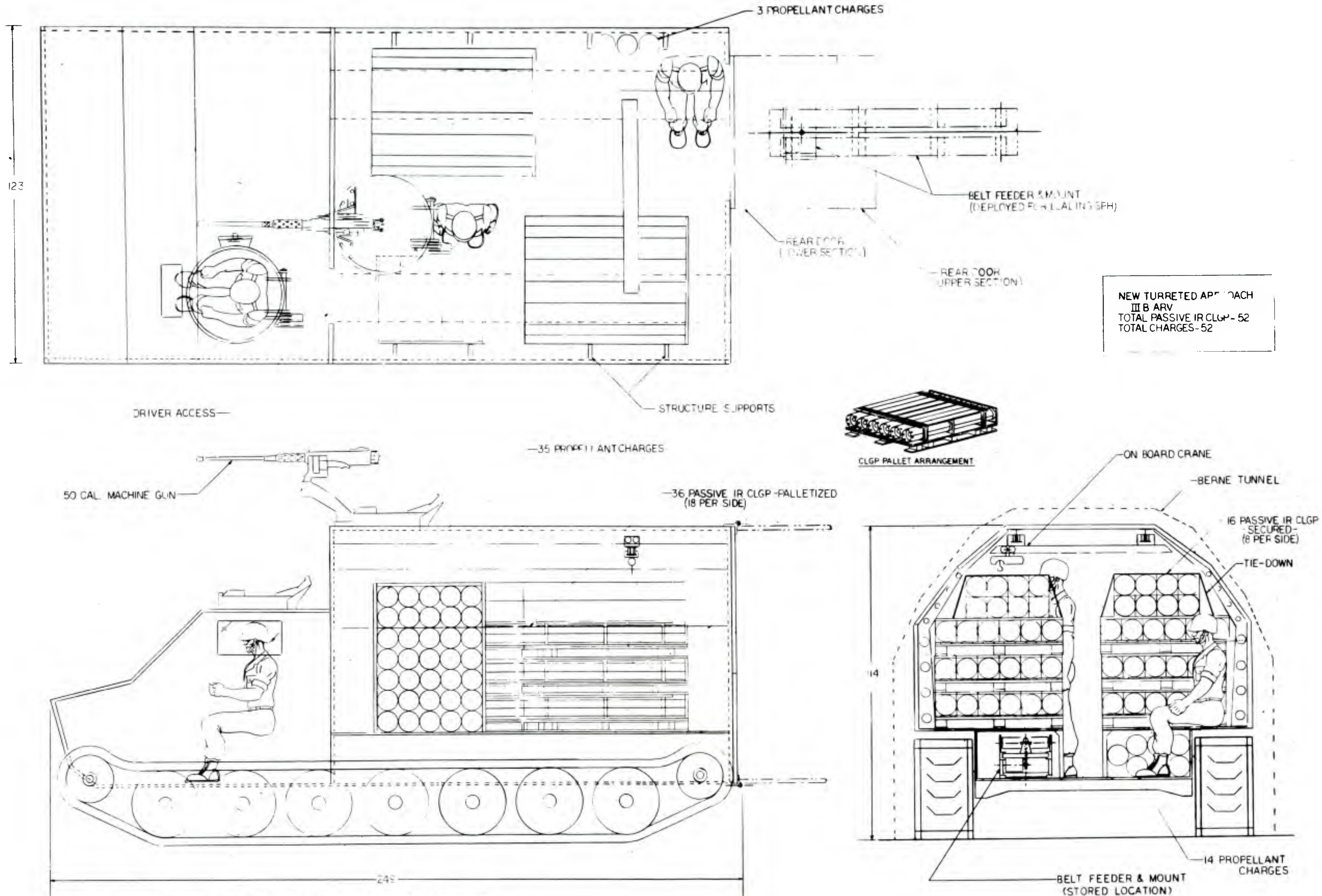



Figure 36 ARV for New Turreted SPH (Concept IIIB)

Table 21

ARV to SPH Resupply Time (Concept IIIB)

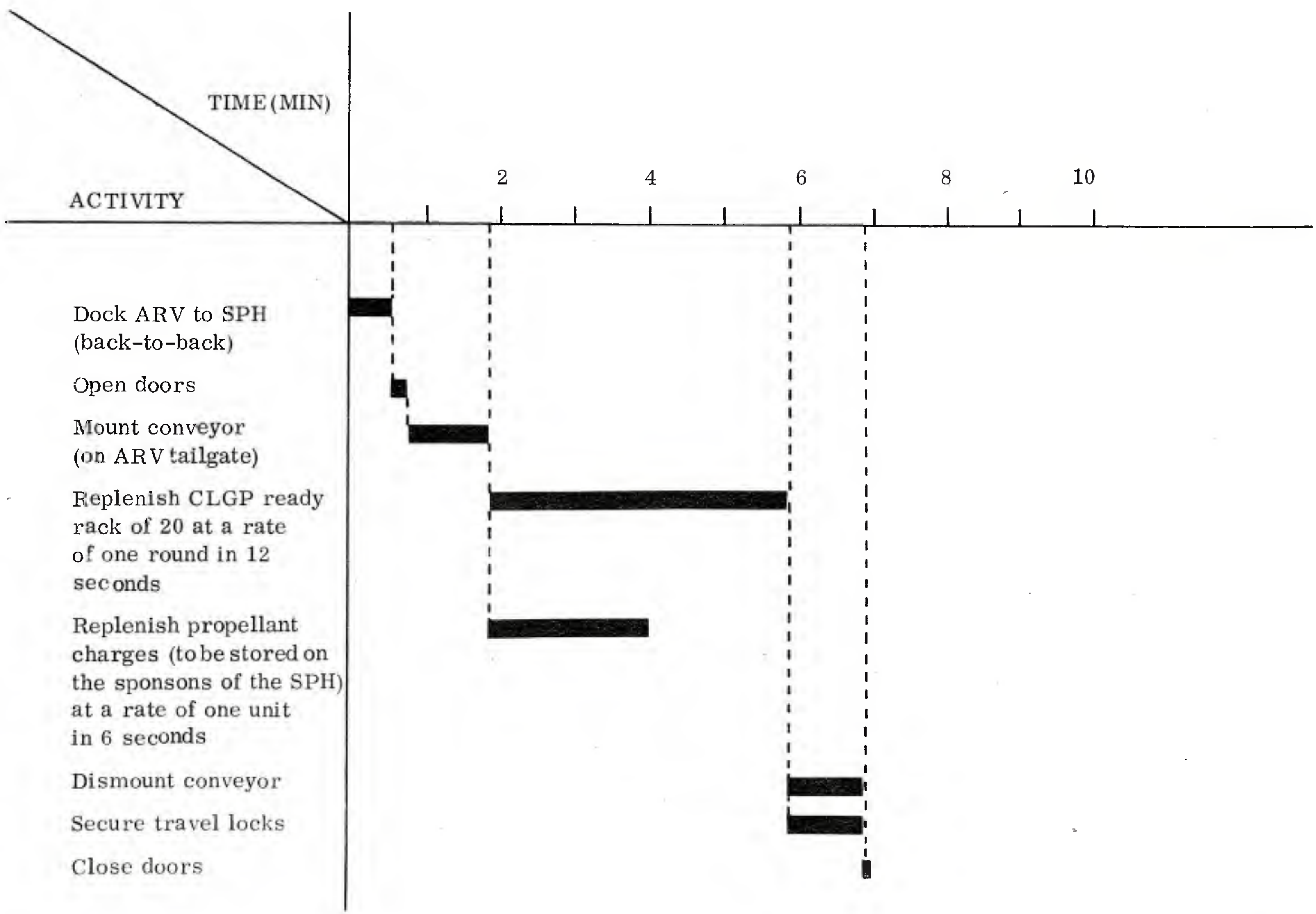
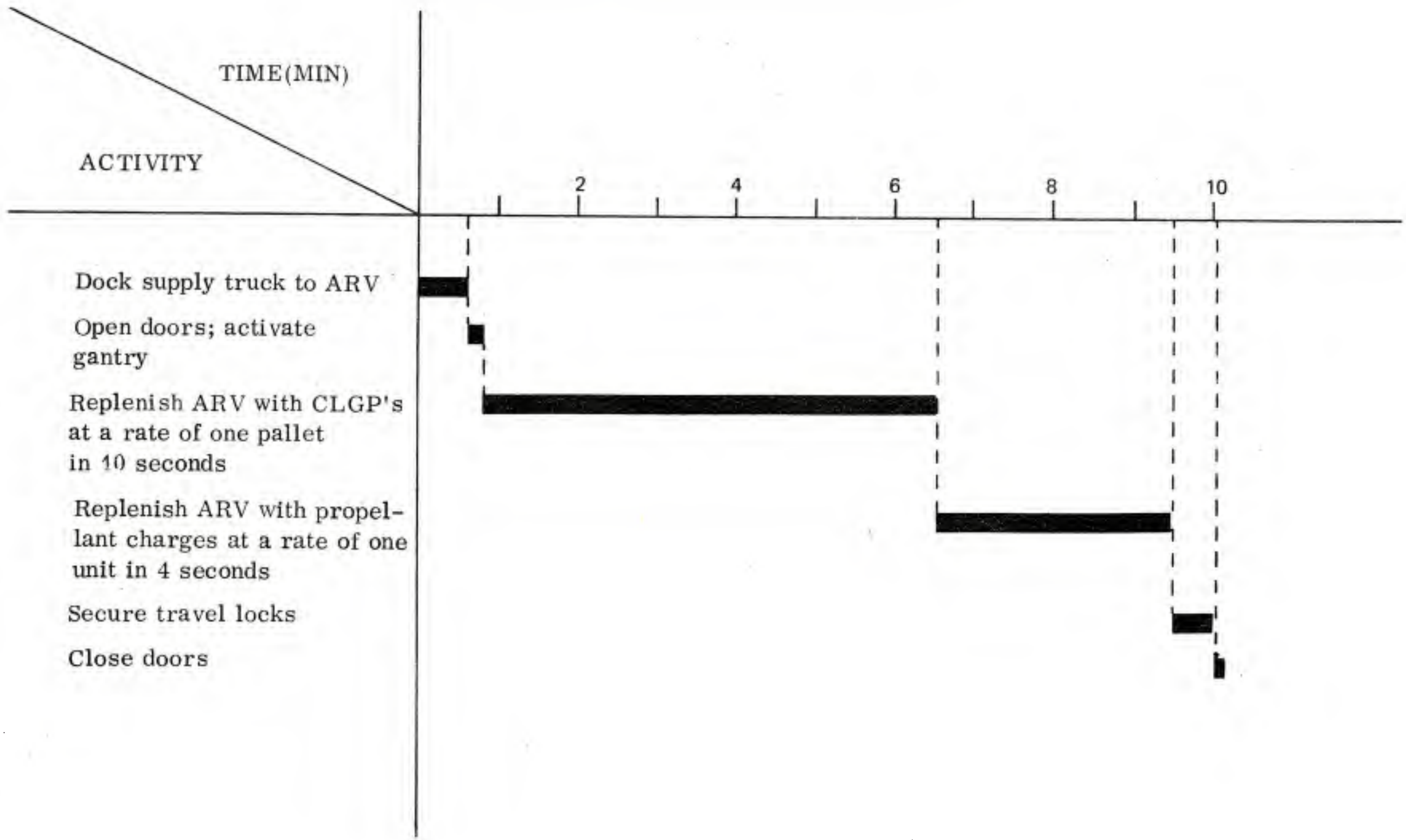


Table 22

Truck to ARV Resupply Time (Concept IIIB)



ARV/Resupply Truck Crew Requirements/Functions:

ARV

Driver - Operates and maintains the vehicle; assists in ammunition handling.

Ammunition handlers (2) - Prepare complete rounds for ARV/SPH interface; are responsible for receiving ammunition unloaded from supply truck.

Resupply truck

Driver - Operates and maintains the truck; unloads the ammunition from the truck to the ARV.

Ammunition Handler - Assists in transfer of ammunition.

Battery Fire Control Vehicle

The battery fire direction center is mounted on a MLRS carrier and is depicted in figure 17. It is described on pages 213 through 219 .

Enhanced M109A2 SPH (Concept IIIC)

General

The enhanced M109A2 SPH (figure 37) is a full-tracked, armored, air-transportable diesel-powered vehicle which carries 18 passive IR CLGP rounds and 20 propellant charges. Its aluminum armor is 1-1/4-inches thick on the top and sides and 1/2-inch thick on the bottom. With its semiautomatic loader it is capable of firing passive IR CLGP rounds at a maximum rate of 12 per 1.7 minutes at ranges up to 22 km. A suspension lockout system provides a stable firing platform and eliminates the need for spades. This concept addresses the rapid firing of 54-inch-long, 138-pound passive IR CLGP rounds. However, it also fires conventional HE and ICM projectiles.

An APU is positioned in the right rear area of the hull. It supplies 25 kw of electrical power for the automatic gun laying system, NBC protection system, land navigation system, communication systems, projectile rammer, and the support systems necessary to the firing mission. This permits shutdown of the main engine during the firing. The APU is powered by a gas turbine which uses diesel fuel from the main engine tanks.

The SPH utilizes the 500-hp Detroit Diesel 8V71T engine and Ordinance torque converter XTG-411-2A transmission. An increase in engine cooling capacity and fuel injection changes permits the present two-cycle, turbocharged 405-hp engine to be increased to 500 HP.

The physical and performance characteristics of this concept are summarized in tables 23 and 24, respectively.

Turret/Armament

The primary armament is a modified M199 155mm cannon with a bore evacuator and slide breech block. A compressible fluid concentric recoil mechanism is used instead of the conventional multiple cylinder mechanism employing a recoil brake and recuperator. Recoil length is anticipated to be approximately 20 inches with a 120,000 pound peak trunnion load. This compressible fluid recoil mechanism encompasses approximately the same envelope as the current M178 mount. Therefore, no extensive modifications to the cab are required.

The traverse and equilibrator mechanisms are the same as in the present M109A2 configuration but the elevating mechanism is altered. In this enhanced configuration, the equilibration/elevation cylinder is used for equilibration purposes only and elevation is accomplished by an electrically powered gear drive system mounted on the turret ring adjacent to the mount rotor. This eliminates the problem of cab roof cracks associated with the present configuration. The cannon may be fired at elevations from -3 degrees to +75 degrees. Air defense and target suppression is accommodated by a .50-caliber machinegun mounted on the cab roof.

Automated Loading System

Ammunition storage capacity consists of 18 projectiles and 20 propellant charges. The projectiles are stored in the ready rack and the propellant charges at the right side of the turret bustle area. The rounds are transferred from the ARV to the SPH by conveyor and are placed on the transporter/rammer which either transfers them to the ready rack for storage or to the modified M199 cannon for firing. Propellant charges are also transferred to the SPH by conveyor and lifted into the turret bustle area for storage.

The ready rack is composed of three six-round stacks for a total of 18 rounds, as shown in (figure 37). Loading of the ready rack is accomplished as follows:

a. The transporter, with projectile, is indexed to one of the stacks.

b. The lifter indexes down and clamps the projectile (plus all other projectiles in the stack).

Table 23

Enhanced M109A2 Concept IIIC - Physical Characteristics

| General Data | SPH | ARV | Ammo Truck |
|---|---|---|---|
| Weight | | | |
| Combat loaded (lb) | 56,200 | 57,400 | 50,000 |
| Net weight (lb) | 53,000 | 38,000 | 27,800 |
| Fuel capacity (gal) | 135 | 163 | |
| Personnel | 3 | 2 | 2 |
| Dimensions | | | |
| Length (in) | 248 | 287 | 339 |
| Width (in) | 124 | 117 | 96 |
| Height (in) | 110 | 112 | 134 |
| Ground clearance (in) | 18 | 17 | 14 |
| Wheel size (in) | 24 | 24 | 53 |
| Track width (in) | 15 | 21 | 8-wheel drive |
| **Firepower** | | | |
| Armament | 155mm cannon<br>.50-cal mg<br>M16 rifles (3) | .50-cal mg<br>M16 rifles (2) | M16 rifles (2) |
| Elevation/depression (deg) | +73/-3 | | |
| On-board traverse (deg) | 360 | | |
| Breech type | Slide block | | |
| Number of rounds carried | 18 | 84 | 84 |
| Family of projectiles | Passive IR CLGP/<br>ICM/HE | Passive IR CLGP/<br>ICM/HE | Passive IR CLGP/<br>ICM/HE |
| Type of ammo handling | Auto load projectile<br>Hand load propellant | X-Y trolly | Crane |

Table 23

Enhanced M109A2 Concept IIIC - Physical Characteristics (Cont'd)

| | SPH | ARV | Ammo Truck |
|---|---|---|---|
| **Mobility** | | | |
| Suspension | Full width torsion bar | Return roller torsion bar | Tapered leaf |
| Lockout on suspension | Yes | | |
| Automotive | | | |
| Engine | Detroit Diesel 8V71T | Cummins VTA-903 | Detroit Diesel 8V92TA |
| Transmission | XTG-411-SA | GE HMPT-500 | Allison HT740D |
| **Survivability** | | | |
| Armor protection (in) | 1.25 aluminum | 1.25 aluminum | |
| NBC prctection | Ventilated facepiece | Ventilated facepiece | Ventilated facepiece |

Table 24

Enhanced M109A2 Concept IIIC - Performance Characteristics

| | SPH | | ARV | | Ammo Truck | | Battery |
|---|---|---|---|---|---|---|---|
| **Firepower** | | | | | | | |
| Min/max range (km) | | | | | | | |
| Passive IR CLGP | 8-22 | | | | | | |
| HE (RAP) | 8-22(30) | | | | | | |
| ICM (RAP) | 8-22(30) | | | | | | |
| Shoot and scoot response | | | | | | | |
| Firing rate (passive IR CLGP) | 12 rds/1.7 min | | | | | | |
| .5 to 2 km relocation time (min) | 15 | | | | | | |
| Max weapon missions/hour | 3 | | | | | | |
| TLE (m) | 85 | | | | | | |
| Battery ammunition usage (rds/day) | | | | | | | |
| 17 target/hour | 4,896 | | | | | | |
| Max firing rate | 6,912 | | | | | | |
| **Ammunition Supply** | | | | | | | |
| Basic load (rds) | 18X8 | + | 84X8 | + | 84X6 | = | 1,320 |
| Ammunition resupply (min) | 6.2 | | 18.5 | | | | |
| Battery resupply rate (17 trucks at battalion) | | | | | | | |
| 40% ASP/60% ATP (rds/day) | | | | | | | 3,246 |
| 100% ATP (rds/day) | | | | | | | 5,712 |

Table 24

Enhanced M109A2 Concept IIIC - Performance Characteristics (Cont'd)

| | SPH | ARV | Ammo Truck | Battery |
|---|---|---|---|---|
| **Mobility** | | | | |
| Cruising range (km) | 320 | 480 | 600 | |
| HP/ton | 17.8 | 17.4 | 17.6 | |
| Max speed-primary roads (kph) | 60 | 64 | 93 | |
| Ground pressure (psi) | 9.8 | 8.0 | 15.2 | |
| Max grade (%) | 60 | 60 | 60 | |
| Verticle obstacle (m) | 0.53 | 0.9 | 0.45 | |

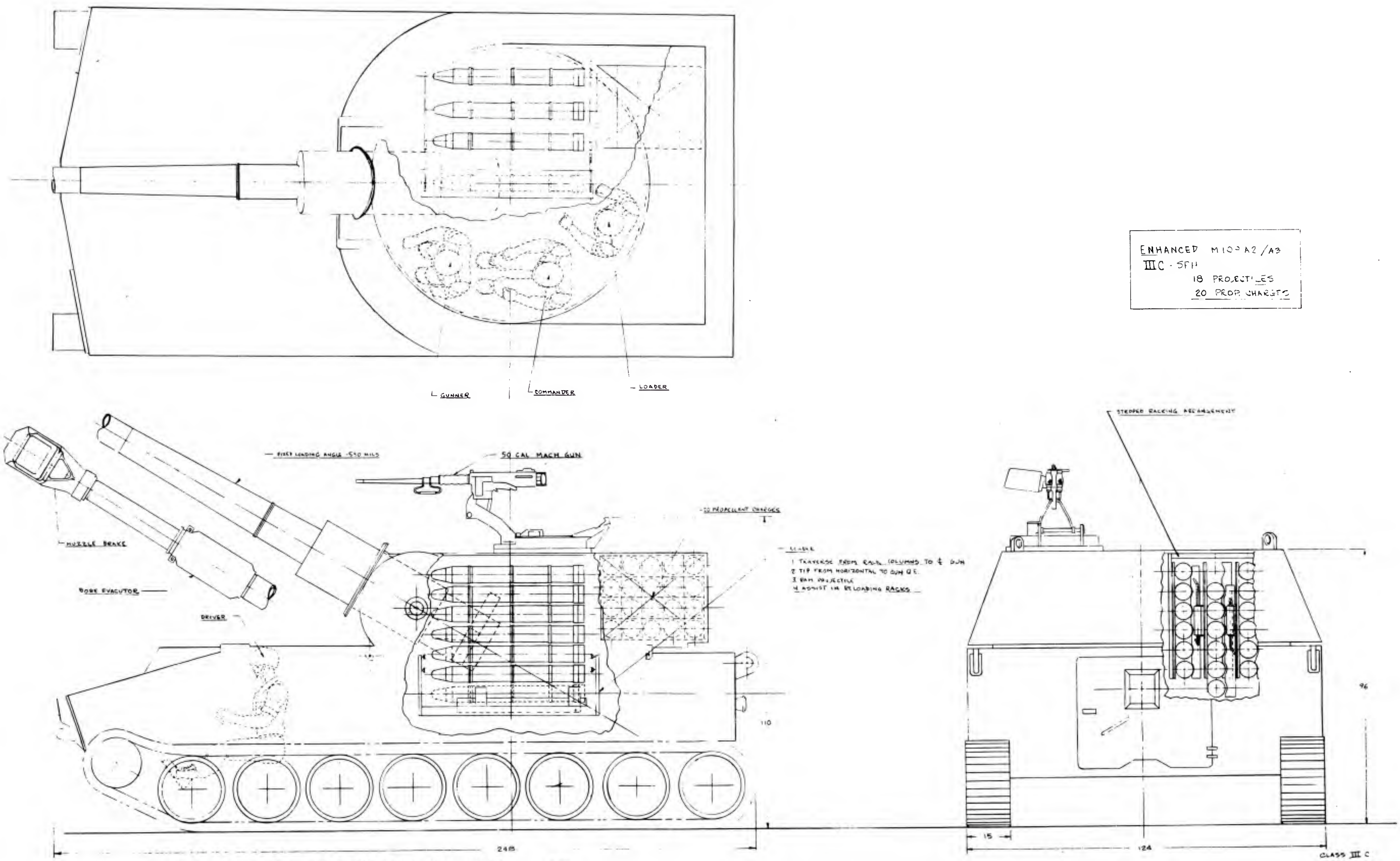



Figure 37 Enhanced M109A2 SPH (Concept IIIC)

c. The retainer is released and the projectiles are indexed upward.

To release projectiles from the ready rack for loading of the cannon, the loading procedure is reversed and a projectile is deposited on the transporter/rammer. Both the ready rack and transporter are suspended from the turret ceiling and thus rotate with the cannon for firing at any azimuth angle. The transporter/rammer is indexed to the gun centerline, its front elevated to 30 degrees to match the cannon's 30-degree loading elevation, the projectile is flick-loaded, and the transporter/rammer is withdrawn to receive another round. The propellant is hand-loaded into the chamber.

### Fire Control and Communication Equipment

The heart of the on-carriage fire control system is the ballistic computer. It receives weapons location data from a land navigation subsystem, gun pitch, roll, and direction from the gun sensors, meterological data from MET MESSAGE, propellant charge temperature from the propellant charge monitor, and the fire mission from the battery FDC. Through a digital message device, the computer instructs the cannoneer as to the selected propellant charge. The autoloader selects the desired projectile from the ready rack. After the gun is loaded and automatically laid to the calcualted azimuth and elevation, the chief of section display indicates the actual weapon settings compared to the specific fire commands. The computer will disable the weapon unless proper verification is made. Upon firing, the velocimeter provides muzzle velocity to the ballistic computer which determines the desired fuze setting. The computer then initiates an RF signal which sets the fuze to the calculated time.

### NBC Protection

Nuclear, biological and chemical protection are provided via the M13A1 ventilated facepiece, protective clothing, and the M8 alarm system. A common filter unit supplies purified filtered air (via hoses) to the crew members. The pressurized air system eliminates much of the breathing resistance normally associated with wearing face masks, and this system (with protective clothing) will allow operation in an open hatch mode. The M25A1 face mask permits the crew to disconnect the forced air supply and abandon the vehicle under complete NBC protection. The NBC equipment is stored on the rear of the right sponson.

### SPH Crew Requirements/Functions

A crew of three; chief of section, driver, and cannoneer is required for SPH operation. The commander gives and follows commands, oversees crew functioning, checks automatic weapon laying, maintains communications with the FDC and ARV as required, coordinates activities, and oversees the operation of AGLS to assure its proper functioning. The driver keeps the chassis and drive train in ready condition, studies local terrain, maintains the engine and APU, and assists the cannoneer during resupply operations. The cannoneer maintains and oversees operation of the autoloader, breaks propellant charges and hand loads them, and receives and stows ammunition during resupply operations.

Ammunition Resupply Vehicle (ARV)

The vehicular components of this concept (figure 38) are the same as those for Concept IIC. However, ammunition storage differs. The ARV carries seven 12-round pallets of propellant charges and 28 three-round pallets of passive IR CLGP. Five propellant charge pallets are stowed across the front of the ARV and the remaining two are stored on a shelf above the right sponson. The 28 projectile pallets are stowed along the sides of the ARV. If desired, the total number of rounds carried may be increased by loading a mixture of CLGP and conventional ammunition.

The projectiles are unpackaged in the ARV and passed to the SPH by conveyor. Following is the transfer procedure:

a. Remove side panels from up to 21 of the accessible CLGP containers.

b. Remove covers from propellant charge containers.

c. Remove packing wedges to release CLGP and transfer CLGP to roller tray (two men required).

d. Push projectile onto the motorized conveyor which is linked to the opening in the SPH hull.

e. Remove propellant charge from storage can, place on roller tray and convey to the SPH.

The ammunition is stowed in the SPH projectile ready rack and bustle propellant stowage area, or fired. After 21 CLGP rounds have been transferred, the emply containers in the ARV must be removed from the stowage area and discharged from the side door. This enables access to 21 additional CLGP rounds. The ARV has a capacity of 84 passive IR CLGP rounds and 84 propellant charges. A time study for resupplying the SPH from the ARV is given in table 25.

ARV Crew Requirements/Functions

A crew of two; driver and ammunition handler, is required for ARV operation. The driver keeps the chassis and drive train in ready condition, studies local terrain, maintains the engine and APU, and assists the ammunition handler

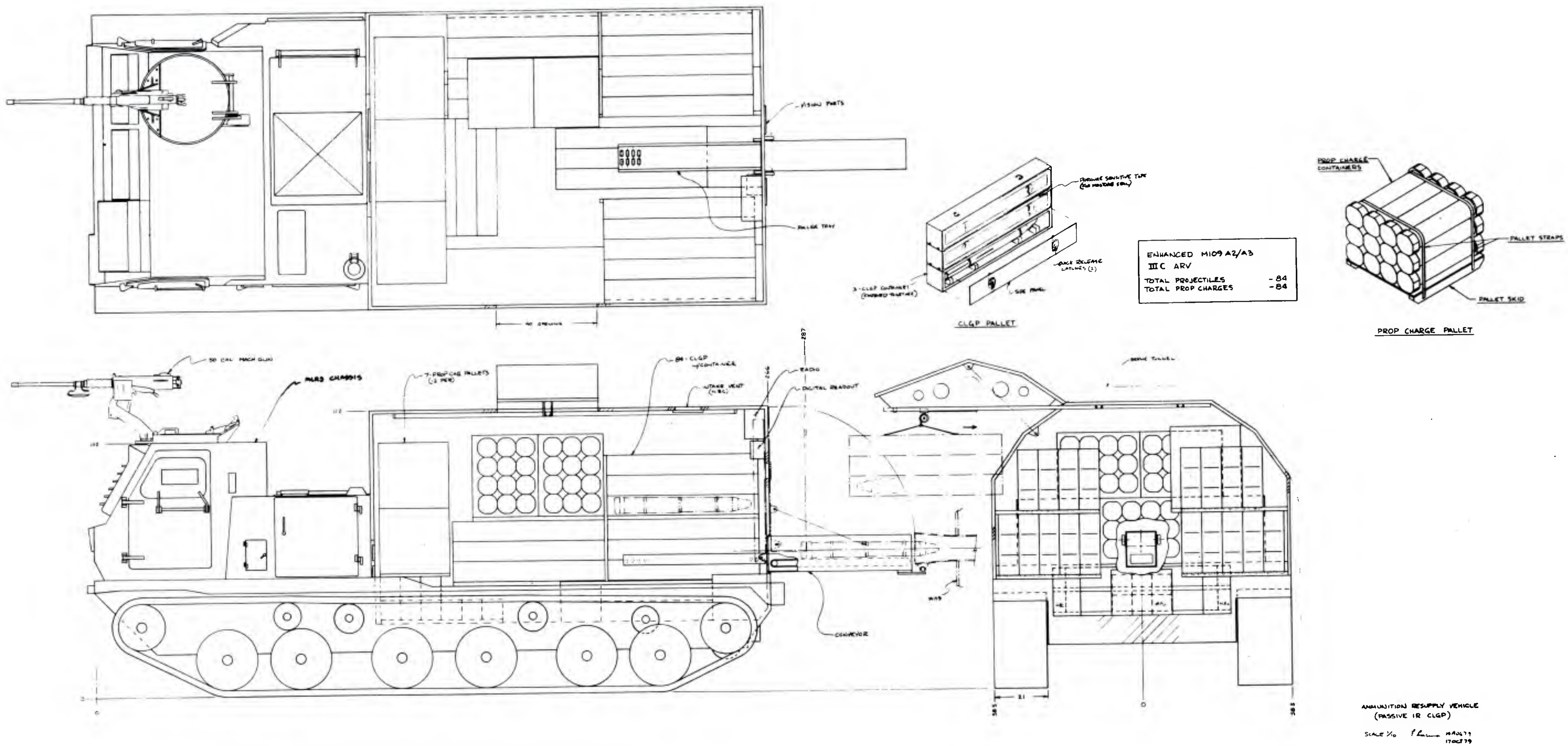



Figure 38 ARV for Enhanced M109A2 SPH (Concept IIIC)

Table 25

ARV to SPH Resupply Time (Concept IIIC)

(See Notes)

1. Docking
2. Transfer 18 projectiles
3. Load ready rack
4. Transfer 18 propellant charges
5. Stow 18 propellant charges
6. Secure vehicle

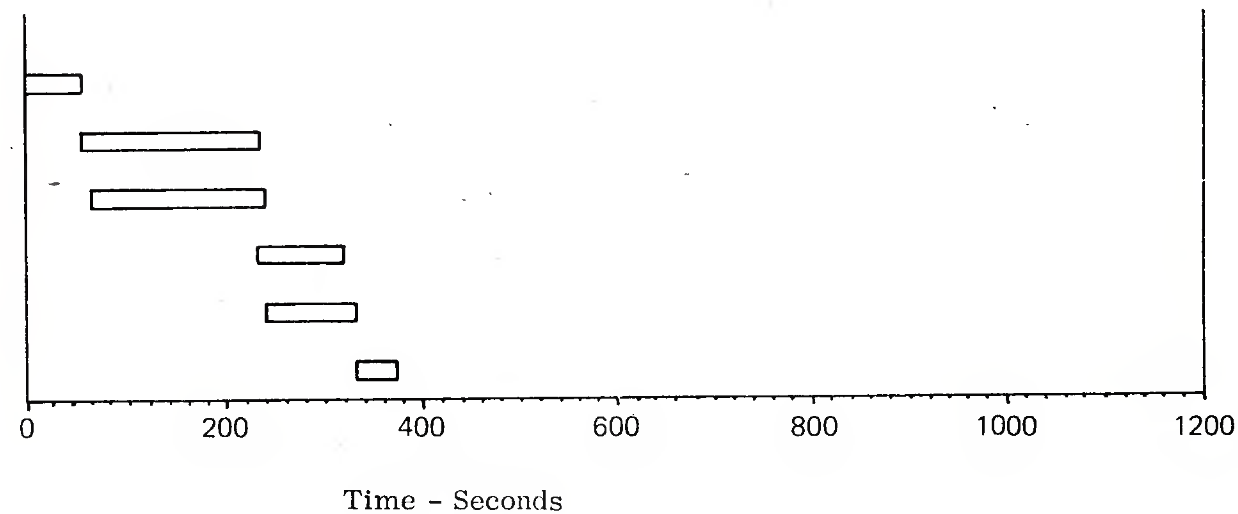


Table 25

Notes

1. 50 sec; docking
The ARV and SPH are docked back-to-back about one foot apart with the ARV's flip-down conveyor extending into the SPH rear door.

2. 180 sec; transfer 18 projectiles to SPH.
Two men remove the side panels from the pallet and lift the passive IR CLGP rounds out of the pallets and place them on the conveyor which carries them into the SPH.

3. 180 sec; load ready rack.
Projectiles arriving in the SPH are guided off the conveyor by two men and onto the transporter. The transporter indexes across to the ready rack where the lifter indexes down, clamps the projectile, and lifts it into the rack. The transporter returns to receive another projectile.

4. 90 sec; transfer 18 propellant charges.
The ammunition handler and ARV driver alternately place single-charge propellant cans on the conveyor which carries them into the SPH.

5. 90 sec; stow 18 propellant charges.
The SPH cannoneer and driver lift the propellant cans off the conveyor and stow them in the turret buslte stowage rack.

6. 40 sec; secure vehicle.
The ARV pulls away from the SPH, the flip-down conveyor is locked in the stowed position; the SPH rear door is closed and the crewmembers return to their duty stations.

during resupply operations. The ammunition handler operates the X-Y trolly, stows ammunition, and maintains communication with the SPH.

Resupply Truck

The ammunition supply truck used with this concept is the 10-ton HMTT associated with Concept IIC. Transfer of CLGP containers (three per pallet) and propellant charges (12 per pallet) from the truck to the ARV is accomplished by means of a truck-mounted crane which transfers the pallets to the ARV trolly hoist. The X-Y trolly extends over the pallets, lifts them 2 to 6 inches, trollies them into the ARV and lowers them into their stowage position where they are locked in place. As the outer pallets are removed from the truck, the truck-mounted crane places additional pallets within the ARV's reach. The crane aboard the truck is working concurrently with the ARV hoist, thereby reducing cycle time. A time study for resupplying the ARV from the truck is shown in table 26.

The ammunition supply truck performs a rather simple mission and, therefore, there is great interchangeability between trucks. The basic requirement is for an all-terrain flat-bed truck with a crane to hand off ammunition pallets to the ARV. The minimum crew would be a driver/crane operator; however, a logistics log keeper is expected to accompany the truck.

Battery Fire Control Vehicle

The battery fire direction center is mounted on a MLRS carrier and is depicted in figure 17. It is described on pages 213 through 219 .

Table 26.

Truck to ARV Resupply Time (Concept IIIC)

(See Notes)

1. Docking
2. Transfer 28 projectile pallets
3. Index 24 projectile pallets
4. Index 7 propellant pallets
5. Transfer 7 propellant pallets
6. Secure vehicle

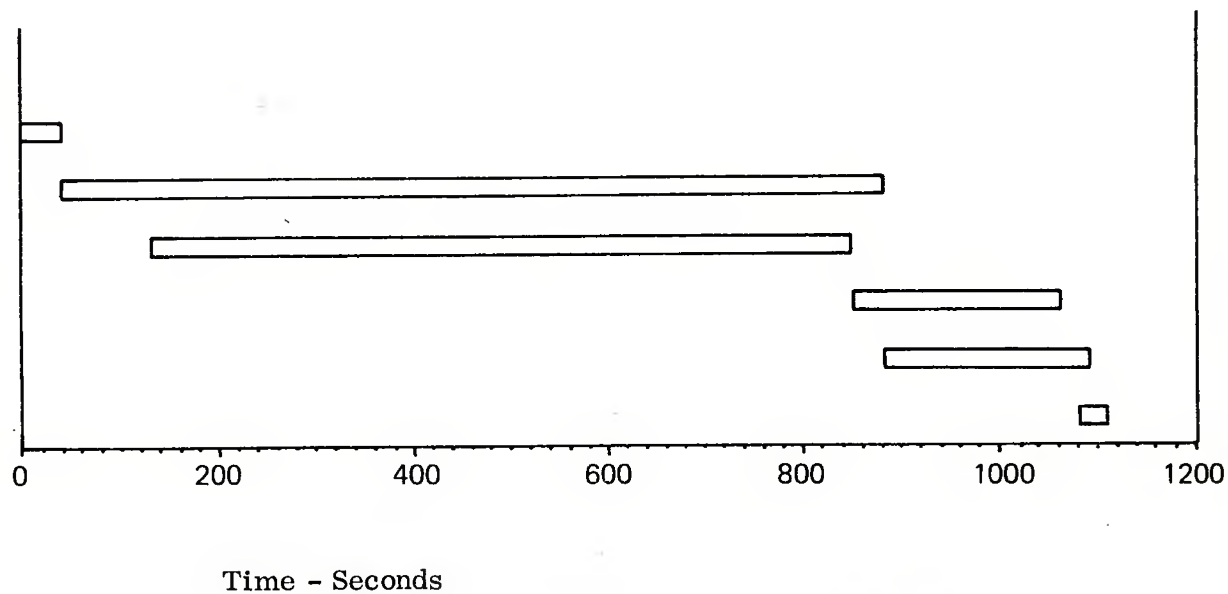


Table 26

Notes

1. 40 sec; docking
   The ARV and HMTT are docked side-to-back 1 to 12 inches apart with the ARV hydraulically activated doors open and the truck's tailgate lowered.

2. 840 sec; transfer 28 projectile pallets to ARV.
   The pallets are individually hoisted off the rear of the truck with the ARV trolly hoist, trollied into the ARV, deposited in their stowage position, and locked in place.

3. 720 sec; index 24 projectile pallets to rear of truck.
   As pallets are removed from the truck, the truck-mounted crane transfers additional pallets to the rear of the truck, so that they are within reach of the ARV trolly hoist.

4. 210 sec; index 7 propellant pallets to rear of truck.
   As pallets are removed from the truck, the truck-mounted crane transfers additional pallets to the rear of the truck within reach of the ARV trolly hoist.

5. 210 sec; transfer 7 propellant pallets to ARV.
   The pallets are individually hoisted off the rear of the truck with the ARV trolly hoist, trollied into the ARV, deposited in their stowage position and locked in place.

6. 30 sec; secure vehicle.
   The truck pulls away from the ARV, the tailgate is closed, the ARV side doors are closed, and the crewmembers return to their duty stations.

Class IV (Extended Range for Region I Targets)

Concept Development Philosophy

The objectives for the Class IV concepts were identical to those for Class II as follows:

a. Defeat moving armored targets in region I.[3]

b. Survive the counterbattery fire threat.

c. Provide ammunition on a timely basis.

In order to meet these objectives, a common philosophy was used for the two concepts developed in this class.

First, in order to defeat the targets it was decided to fire an "area type" round, accurately and with little time delay, in and around the target complex. Since a major mission of a 155mm SP battery weapon system is target servicing, this lead to the selection of scatterable mines as the high-density round providing the antiarmor firepower. Also, since a large number of targets are identified in a short period of time, each battery concept was required to have the following firepower characteristics:

a. Fire a burst of 18 rounds at the highest practicable firing rate.

b. Reduce the TLE to 130 meters.

c. Provide a fast response capability so that the rounds could be fired immediately after the FO identifies and locates the target.

Second, in order to survive, it was decided to move the SPH back from the FEBA so that they were out of range of over 90% of the Soviet cannon counterbattery fire threat. In addition, the Class IV concepts are visualized to operate in a familiar battery configuration and avoid the command and control requirements which occur with the Class II and Class III concepts. However, the Class IV concepts require an improved long-distance communication and data transmission capability from FIST elements at the FEBA.

In evaluating the Class II and III concepts, it appeared from an engineering standpoint that the casemate approach for an SPH had several advantages over turreted approaches; therefore, the following battery concepts were developed:

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[3] While the Class IV concepts were optimized to defeat armored targets, an ability was retained to provide massed fire in the traditional cannon artillery role

a. Concept IVA consists of a casemate SPH firing a longer, heavier, boosted, scatterable mine round, a companion ARV, and a battery fire control vehicle integrated with FIST.

b. Concept IVB consists of a casemate SPH with a larger cannon firing a spin-stabilized, scatterable-mine round, a companion ARV, and a battery fire control vehicle integrated with FIST.

Casemate SPH (Concept IVA)

General

This concept, figure 39, is an armored SPH of casemate design with extended range capability. It is equipped with a cannon similar to the M199, but adds a bore evacuator and uses a slide block breech. Extended range is achieved by shooting a boosted, scatterable mine/ICM projectile. A concentric compressible fluid recoil mechanism is used instead of the conventional type with its recoil brake and recuperator. Except for its fire control and communications setup, and its ARV, this concept is essentially the same as Concept IIIA.

The physical and performance characteristics are summarized in tables 27 and 28, respectively.

Fire Control and Communication Equipment

The SPH has its own on-board ballistic computer, velocimeter, and land navigation. Also included is a chief of section display and a radio capable of digital communications. Due to the greater distance between the FO and the SPH, the conventional FM radio will be range limited; therefore, either an AM radio or a packet radio with its inherent automatic data distribution will be employed.

Ammunition Resupply Vehicle

See figure 40 for an outline drawing of the ARV.

Battery Fire Control Vehicle

The battery fire direction center is mounted on a MLRS carrier and is depicted in figure 17. It is described on pages 213 through 219 .

Casemate SPH (Concept IVB)

General

This concept, figure 41, is an armored SPH of the casemate type. Its mis-

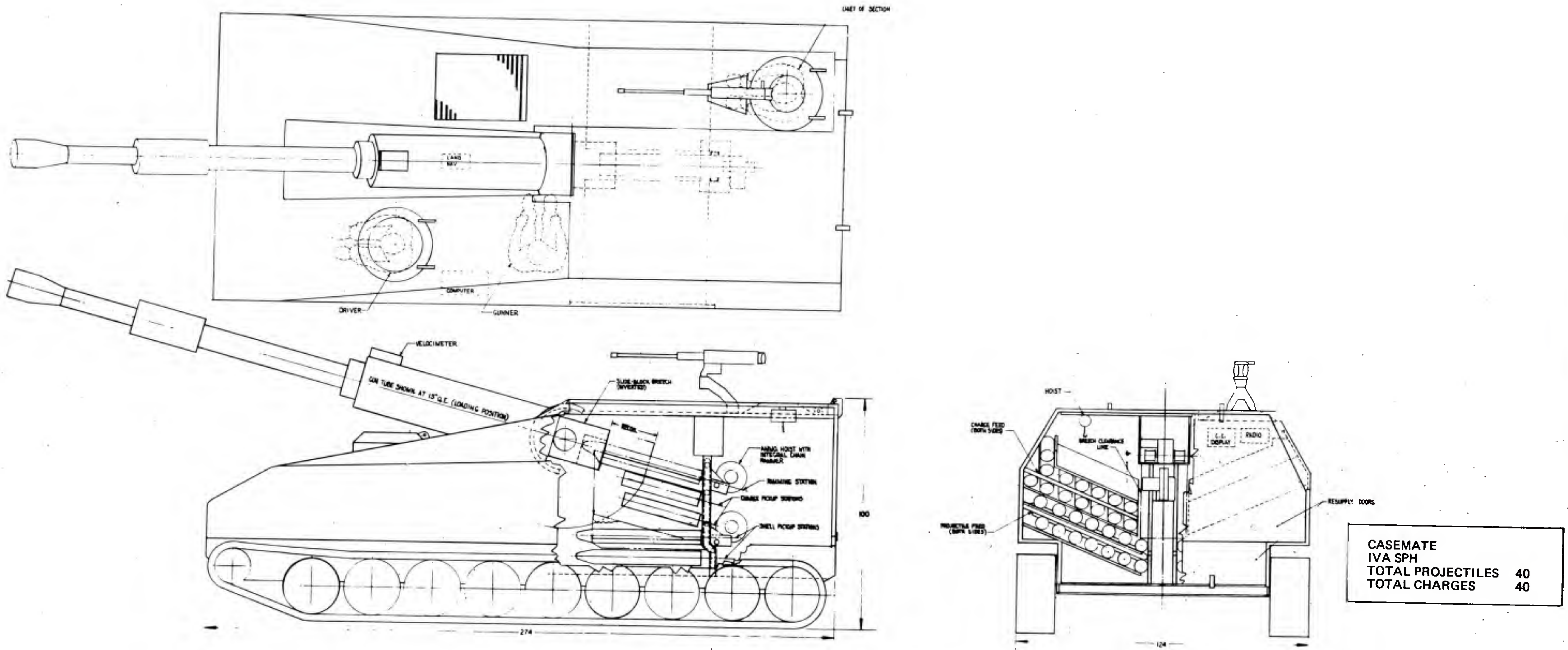



Figure 39 Casemate SPH (Concept IVA)

TABLE 27

Casemate Concept IVA - Physical Characteristics

| General data | SPH | ARV | Ammo Truck |
|---|---|---|---|
| Weight | | | |
| Combat loaded (lb) | 67,000 | 59,000 | 48,840 |
| Net weight (lb) | 55,000 | 30,000 | 27,800 |
| Fuel capacity (gal) | 318 | 318 | 100 |
| Personnel | 3 | 2 | 2 |
| Dimensions | | | |
| Length (in) | 274 | 274 | 349 |
| Width (in) | 124 | 124 | 96 |
| Height (in) | 98 | 90 | 108 |
| Ground clearance (in) | 17 | 17 | 17 |
| Wheel size (in) | 24 | 24 | 24x20.5R |
| Track width (in) | 16 | 16 | - |
| Firepower | | | |
| Armament | Modified M199 155mm cannon, .50- cal mg | .50-cal mg | |
| Elevation/depression (deg) | +75/0 | | |
| On-board traverse (deg) | ±5 | | |
| Breech type | Slide block | | |
| Number of rounds carried | 40 | 120 | 60 |
| Family of projectiles | Boosted scatterable mine/ICM/HE | Boosted scatterable mine/ICM/HE | Boosted scatter-able mine/ICM/HE |
| Type of ammo handling | Auto load/auto ram | Power assist (gantry) | Crane |

TABLE 27

Casemate Concept IVA - Physical Characteristics (Cont'd)

| Mobility | SPH | ARV | Ammo Truck |
| --- | --- | --- | --- |
| Suspension | Full width torsion bar | Full width torsion bar | Walking beam |
| Lockout on suspension | Yes | | |
| Automotive | | | |
| Engine | Cummins VTA-903 | Cummins VTA-903 | 440 Diesel |
| Transmission | AMX-1000 | AMX-1000 | Hydrokinetic Automatic |
| **Survivability** | | | |
| Armor protection (in) | 1. 25 aluminum (same as M109) | 1. 25 aluminum | |
| NBC protection | Hybrid | Hybrid | Ventilated face-piece |

TABLE 28

Casemate Concept IVA - Performance Characteristics

| Firepower | SPH | | ARV | | Ammo Truck | | Battery |
|---|---|---|---|---|---|---|---|
| Min/max range (km) | | | | | | | |
| Boosted scatterable mine/ICM/HE | 8-35 | | | | | | |
| Shoot and scoot response | | | | | | | |
| SPH firing rate | 18 rds/2.2 min | | | | | | |
| .5 to 2 km relocation time (min) | 15 | | | | | | |
| Max weapon missions/hour | 3 | | | | | | |
| TLE (m) | 130 | | | | | | |
| Battery ammunition usage (rds/day) | | | | | | | |
| 17 target/hour | 7,344 | | | | | | |
| Max firing rate | 10,368 | | | | | | |
| **Ammunition Supply** | | | | | | | |
| Basic load (rds) | 8x40 | + | 8x120 | + | 6x96 | = | 1,856 |
| Battery resupply rate (17 trucks at battalion) | | | | | | | |
| 40% ASP/60% ATP (rds/day) | | | | | | | 3,712 |
| 100% ATP (rds/day) | | | | | | | 6,528 |
| **Mobility** | | | | | | | |
| Cruising range (km) | 500 | | 500 | | | | |
| HP/ton | 18 | | 20 | | | | |
| Max speed-primary roads (kph) | 60 | | 60 | | | | |
| Ground pressure (psi) | 10 | | 9 | | | | |
| Max grade (%) | 60 | | 60 | | | | |
| Verticle Obstacle (m) | 0.53 | | 0.53 | | | | |

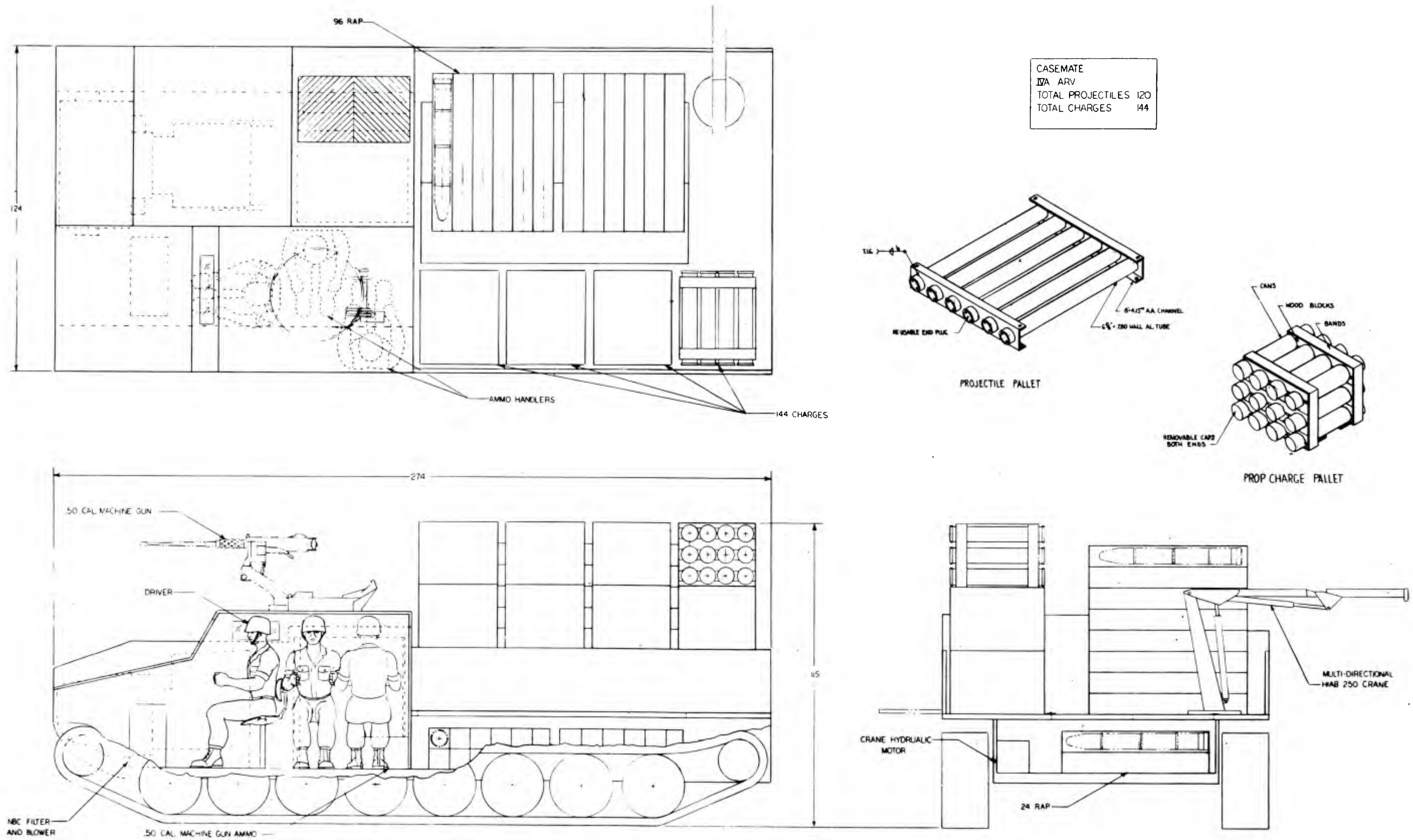



Figure 40 Casemate ARV (Concept IVA)

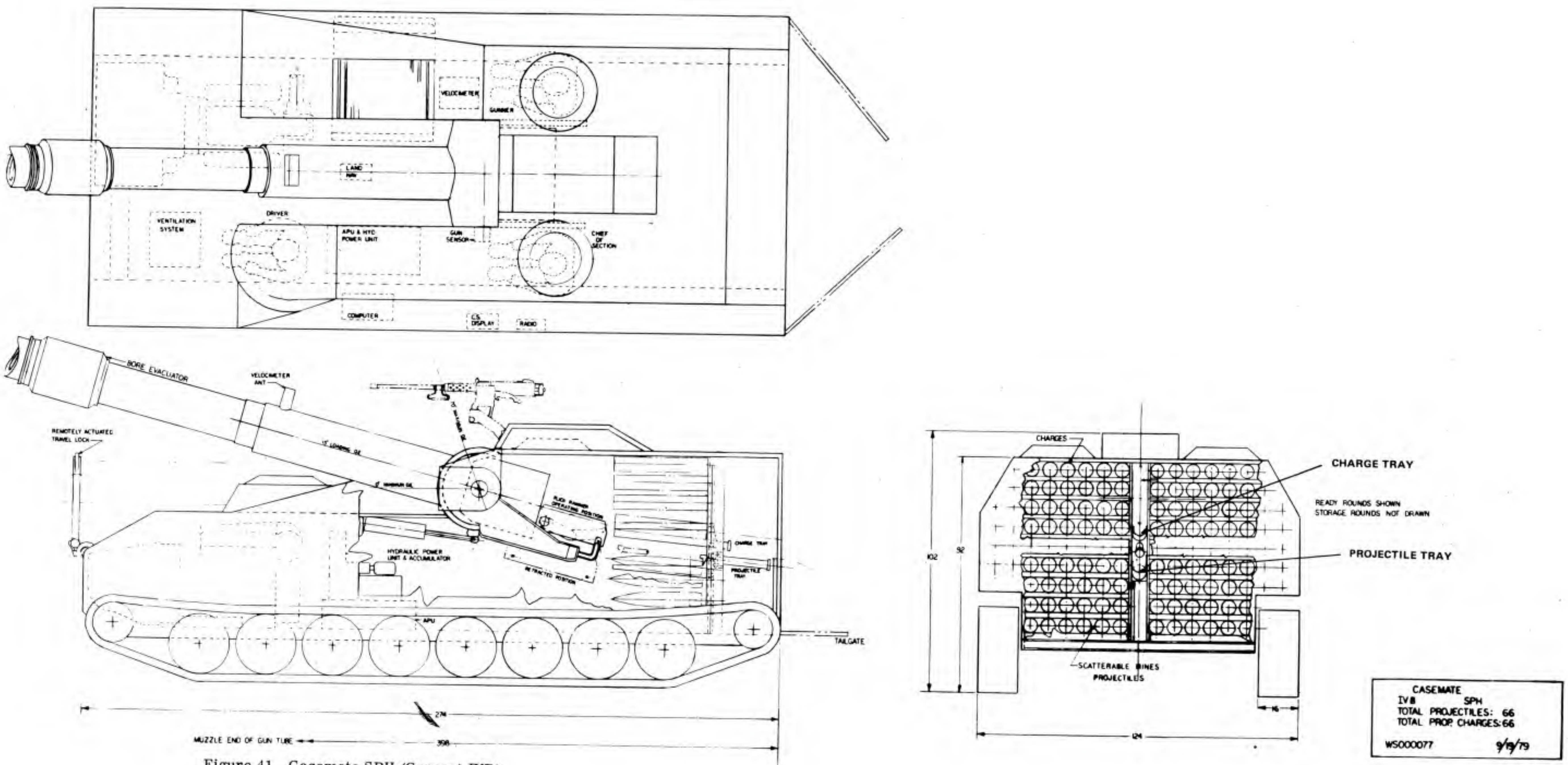



Figure 41 Casemate SPH (Concept IVB)

sion is the servicing of targets at extended ranges. Extended range is achieved by using the howitzer test bed III (HTB III) high-pressure cannon firing unboosted scatterable-mine projectiles. Most aspects of this concept are the same as those of Concept IIA with the exception of the loader/ready storage and the heavy-walled cannon.

The physical and performance characteristics of Concept IVB are summarized in tables 29 and 30, respectively.

Armament

The HTB III cannon uses a multi-lug slide block breech and concentric compressible fluid recoil mechanism. Because of the high muzzle velocities and pressures, the projectiles are subjected to higher loads than in the Class II concepts. Tube pressure is expected to be 60 kpsi with a maximum design pressure of 77.4 kpsi. The cheif of section and gunner are located 5 inches further outboard to clear the larger recoil envelope. (This in comparison with Concept IIA using the modified M199 cannon.) The cannon recoils 20 inches and its larger breech has caused the ammunition storage rack to be relocated 5 inches to the rear. Schemes for making major deflection corrections with an APU, and for remotely securing the gun tube for travel, are similar to those used in the Class II concepts.

Automated Loading System

A total of 66 projectiles and 66 propellant charges are stored in a ready rack located behind the gun. Four additional complete rounds may be stored on each side in the sponson areas forward of the ready rack for a total of 74 rounds. The bottom half of the honeycomb contains the projectiles and the upper half contains the charges. A vertical "alley way" divides the honeycomb into two halves and contains the projectile and propellant charge elevator trays. Under the gun is a flick rammer which folds up when not in use (figure 41). To load the cannon, the tube is moved to 15 degrees elevation and the projectile elevator tray accepts a projectile from one of the horizontal tiers on either side of the "alley way". The projectile moves in-board via a pawl arrangement. The elevator tray aligns with the ram tray which has moved from its stowed position to its operational position and the projectile is transferred to this tray and flicked into the cannon. As the projectile elevator returns to pick up another projectile, the charge elevator tray in the upper half of the honeycomb picks up a charge which it aligns with the ram tray. The charge is flicked into the chamber, the breech closes, and the cannon returns to its firing elevation. The charge elevator returns to pick up the next charge and the ram tray moves to its stowed position. The cannon is ready to fire. The maximum firing rate is anticipated to be 7.5 rounds per minute or 18 rounds in 2.4 minutes. See figure 42 for an operational view of the autoloader.

Fire Control and Communication Equipment

The SPH has its own on-board ballistic computer, velocimeter, and land

TABLE 29

Casemate Concept IVB - Physical Characteristics

| General Data | SPH | ARV | Ammo Truck |
|---|---|---|---|
| Weight | | | |
| Combat loaded (lb) | 72,000 | 58,000 | 51,000 |
| Net weight (lb) | 61,000 | 29,000 | 27,800 |
| Fuel capacity (gal) | 318 | 318 | - |
| Personnel | 3 | 2 | 2 |
| Dimensions | | | |
| Length (in) | 274 | 274 | 208 (bed) |
| Width (in) | 124 | 124 | 91 |
| Height (in) | 109 | 98 (gantry depressed) | - |
| Ground clearance (in) | 17 | 17 | 17 |
| Wheel size (in) | 24 | 24 | 24x20.5R |
| Track width (in) | 16 | 16 | - |
| Firepower | | | |
| Armament | 155mm HTB III cannon, .50-cal mg | .50-cal mg | |
| Elevation/depression (deg) | +75/0 | - | - |
| On-board traverse (deg) | ±5 | - | - |
| Breech type | Slide block multi lug | - | - |
| Number of rounds carried | 66 | 144 | 120 |
| Family of projectiles | Scatterable mine/ICM/HE | Scatterable mine/ICM/HE | Scatterable mine/ICM/HE |
| Type of ammo handling | Auto load/auto ram | Gantry | Crane |

TABLE 29

Casemate Concept IVB - Physical Characteristics (Cont'd)

| Mobility | SPH | ARV | Ammo Truck |
|---|---|---|---|
| Suspension | Full width torsion bar | Full width torsion bar | Walking beam |
| Lockout on suspension | Yes | - | - |
| Automotive | | | |
| Engine | Cummins VTA-903 | Cummins VTA-903 | 440 diesel |
| Transmission | AMX-1000 | AMX-1000 | Hydrokinetic automatic |
| **Survivability** | | | |
| Armor protection (in) | 1. 25 aluminum (same as M109) | 1. 25 aluminum (cab only) | - |
| NBC protection | Hybrid | Hybrid | Ventilated facepiece |

TABLE 30

Casemate Concept IVB - Performance Characteristics

| Firepower | SPH | | ARV | | Ammo Truck | | Battery |
|---|---|---|---|---|---|---|---|
| Min/max range (km) | | | | | | | |
| Scatterable mine/ICM/HE | 8-35 | | | | | | |
| Shoot and scoot response | | | | | | | |
| Firing rate | 18 rds/2.4 min | | | | | | |
| .5 to 2 km relocation time (min) | 15 | | | | | | |
| Max weapon missions/hour | 3 | | | | | | |
| TLE (m) | 85 (due to high muzzle velocity) | | | | | | |
| Battery ammunition usage (rds/day) | | | | | | | |
| 17 target/hour | 7,344 | | | | | | |
| Max firing rate | 10,368 | | | | | | |
| **Ammunition supply** | | | | | | | |
| Basic load (rds) | 8x66 | + | 8x144 | + | 6x120 | = | 2,410 |
| Ammunition resupply (min) | 12 | | 18 | | - | | |
| Battery resupply rate (17 trucks at battalion) | | | | | | | |
| 40% ASP/60% ATP (rds/day) | | | | | | | 4,640 |
| 100% ATP (rds/day) | | | | | | | 8,160 |
| **Mobility** | | | | | | | |
| Cruising range (km) | 500 | | 500 | | 600 | | |
| HP/ton | 16.4 | | 18.9 | | 17.3 | | |
| Max speed-primary roads (kph) | 61 | | 61 | | 89 | | |
| Ground pressure (psi) | 12.7 | | 11 | | - | | |
| Max grade (%) | 60 | | 60 | | 60 | | |
| Verticle obstacle (m) | 0.5 | | 0.5 | | 0.4 | | |

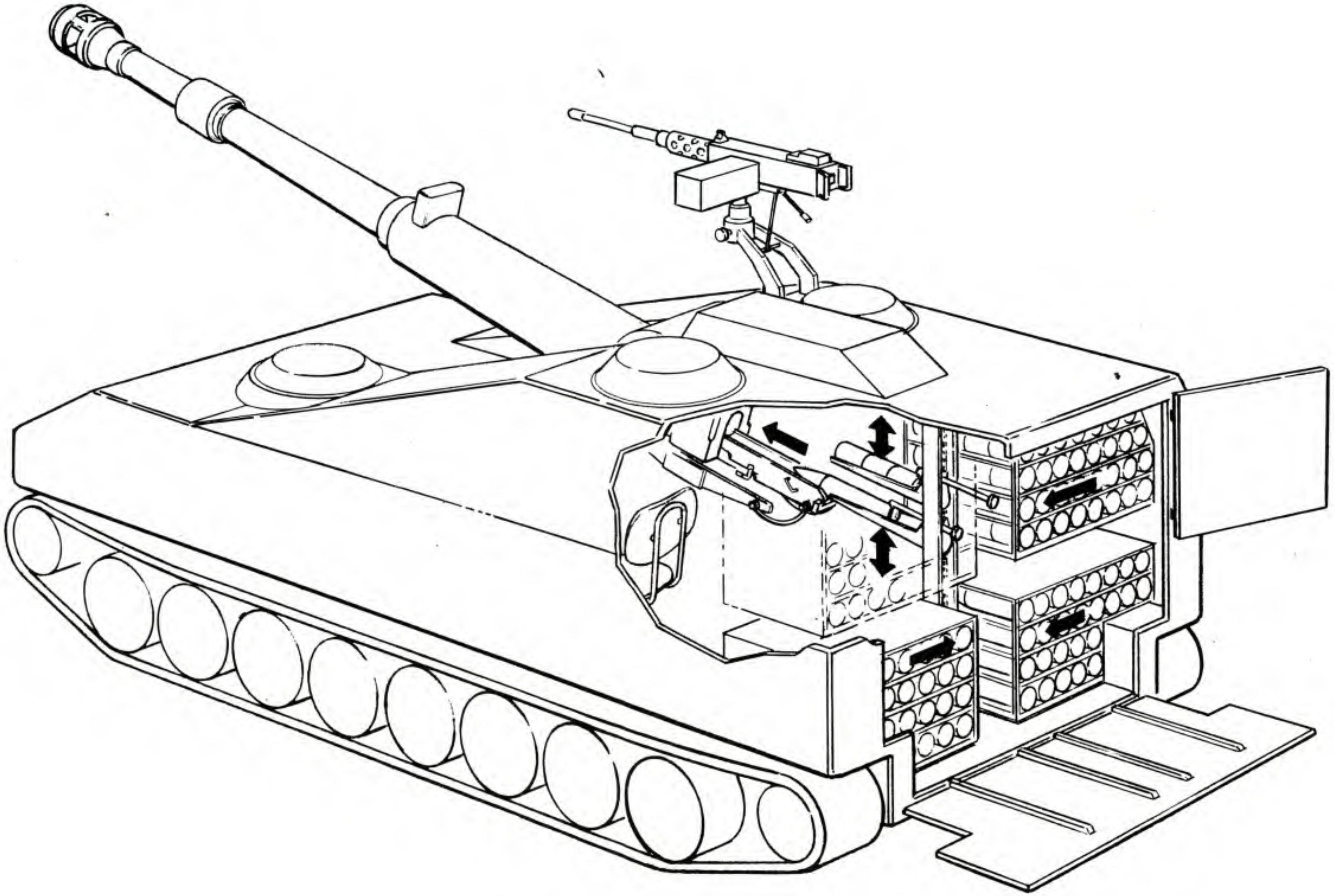


Figure 42 Operational View of Autoloader (Concept IVB)

navigation. Also included is a chief of section display and a radio capable of digital communications. Due to the greater distance between the FO and the SPH, the conventional FM radio will be range limited; therefore, either an AM radio or a packet radio with its inherent automatic data distribution will be employed.

NBC Protection

A ventilated facepiece is employed. A positive pressure system is also utilized. Using a hybrid system, the SPH can fire 66 rounds; 58 rounds can be fired automatically from the ready rack and 8 can be fired manually before it becomes necessary to resupply. Resupply would take place in a prearranged "clean" area an appropriate distance from any contaminated area.

SPH Crew Requirements/Functions:

Driver - Operates and maintains vehicle. Also assists with ammunition handling.

Chief of section - Responsible for communication and coordination of activities. Also uses .50-caliber machinegun.

Gunner - Operates fire control equipment and handles ammunition.

Ammunition Resupply Vehicle (ARV)

This ARV (figure 43) is similar to the Concept IIA ARV with the following differences: A two man crew instead of a three man crew is used; the crew compartment is smaller, which permits a larger cargo area to accommodate the larger propellant charge pallets; and the cargo is stored differently. A total of 144 complete rounds are on board; 12 pallets of projectiles and 12 pallets of charges. The ARV incorporates power assist features which reduce time and labor.

The ARV is docked end-to-end with the SPH; the SPH tailgate is lowered and its rear access door is opened. The ARV, prior to docking, has had its gantry raised to its operating height, and has started extension of its horizontal boom. The projectiles are palletized three across and four deep. If the SPH ready racks are depleted, a total of 48 projectiles (4 pallets) could be transferred from the ARV into the SPH by directly aligning the pallet to the rack and pushing the projectiles into the ready racks (figure 44) with no lifting involved. (The pallet center lines match the ready rack center lines.) These 48 ready racks are located in the lower half of the matrix. The remaining outboard spaces and the spaces which form a horizontal line separating the charges (upper half) from the projectiles (lower half) are hand loaded. The aforementioned projectile pallets are lifted from their stored position on the ARV with the gantry, starting from the cargo area nearest the SPH. The gantry has the freedom to move fore/aft, laterally, and up/down. The winch lifts the pallet and can be moved laterally on the winch beam. Fore/aft motion is attained by moving the winch beam

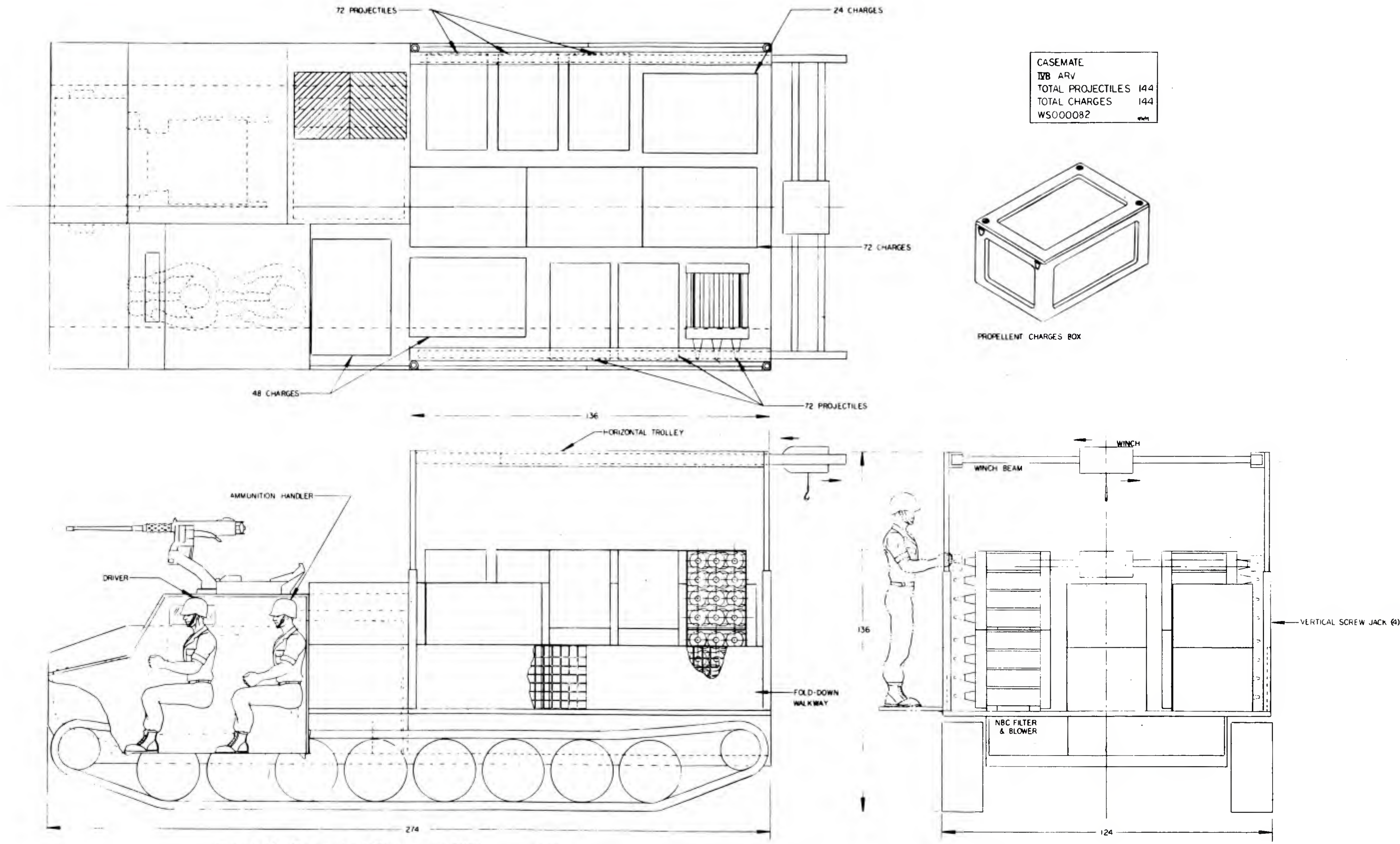



Figure 43 Casemate ARV (concept IVB)

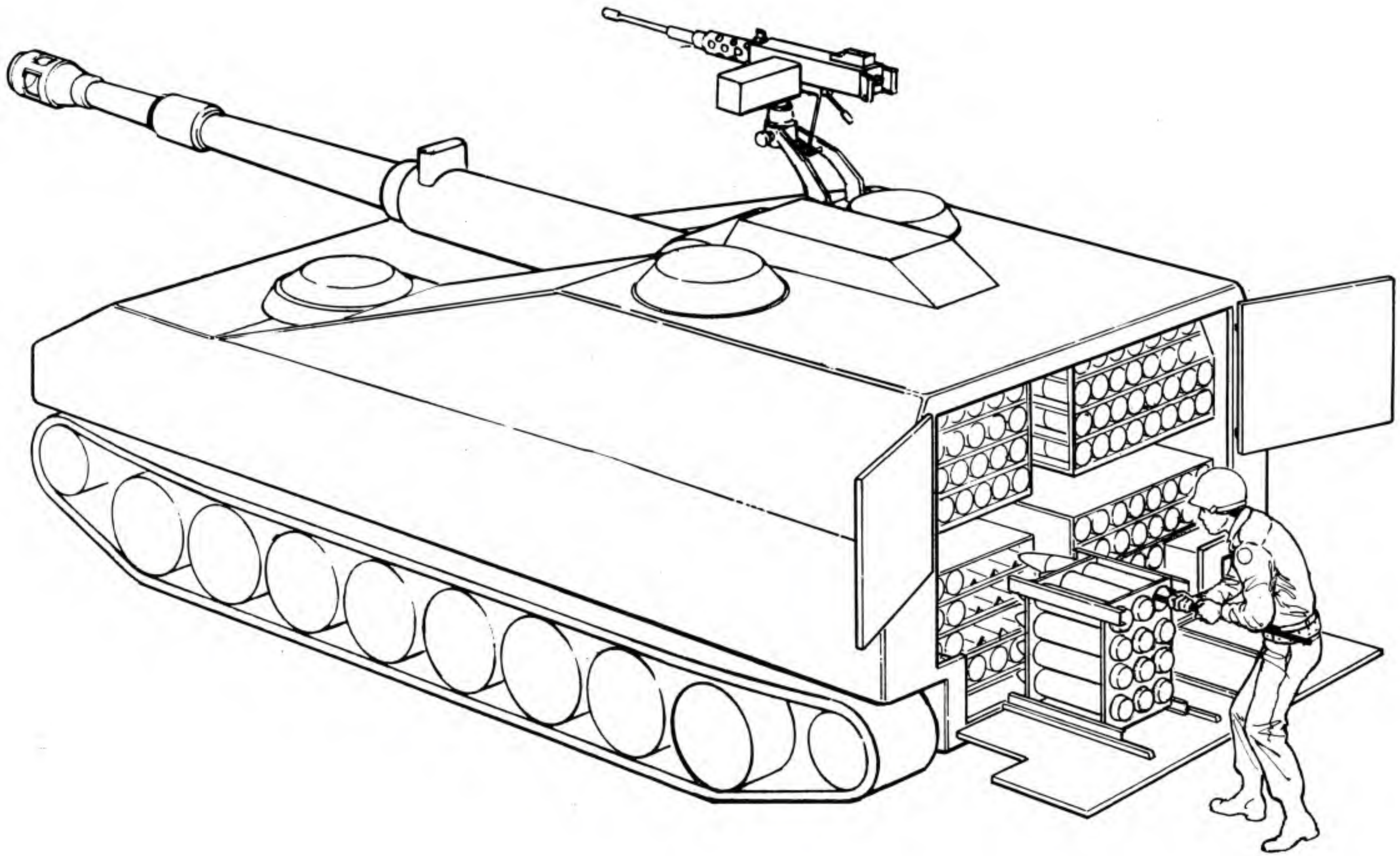


Figure 44 Push Loading Projectile from Pallet into Ready Rack (Concept IVB)

along the horizontal trolly. The projectile pallets are placed, one at a time, onto the SPH tailgate and aligned with the tailgate's pallet guides.

After replenishing the projectiles, the gantry transports the propellant charge pallets, one at a time, and drops them onto the tailgate. The tailgate has, in the meantime, been raised to facilitate manual loading of the charges. After the transfer, the vehicles undock and the SPH tailgate is retracted and its doors are closed. (The closed doors provide travel retention for the projectiles.) It is estimated that the time required to replenish the SPH would be approximately 16 minutes. This estimate is based upon the time chart generated for Concept IIA which has a similar configuration.

Resupply Truck

The ammunition supply truck (figure 15) is an articulated 8 x 8 vehicle capable of carrying 120 projectiles with their fuzes and propellant charges. The procedure for resupplying the ARV from the truck is shown in figure 16 and consists of the following steps:

1. Drive the truck behind the ARV to form a T-configuration.

2. Extend the ARV gantry over the truck bed to pick up pallet (gantry can be extended to center of truck bed).

3. Transfer pallet from truck to ARV.

4. Repeat process until truck is empty or ARV is full.

As the gantry removes pallets from the truck bed and an area is cleared, the truck is moved forward to bring additional pallets into the range of the gantry. When the entire side and center areas of the truck have been emptied of pallets, the truck is turned around to provide access to the remaining pallets. An alternative to this operation (in the case of tight quarters or limited turning area) would be to use the gantry to drag the pallets across the truck bed by hooking to the lower part of the pallet or by using the truck crane to preposition the pallets for the gantry pickup. This last method would not extend the total time since the operation would be concurrent with the gantry movement in storing the pallets in the ARV.

ARV/Resupply Truck Crew Requirements/Functions:

ARV

Driver - Operates and maintanins ARV and assists in ammunition transfer.

Ammunition handler - Prepares pallets, rounds, and ARV for transfer; helps load SPH.

Resupply Truck

Driver - Operates and maintains resupply vehicle. Also assists in loading the ARV by operating the truck-mounted crane.

Ammunition handler - Assists in transferring ammunition.

Battery Fire Control Vehicle

The battery fire direction center is mounted on a MLRS carrier and is depicted in figure 17. It is described on pages 213 through 219.

Class V (Extended Range for Counterbattery Fire)

Concept Development Philosophy

The Class V concepts were systhesized to meet the following main objectives:

a. Augment 8-inch SPH and MLRS in the counterbattery fire role in order to protect US infantry and armored forces from Soviet artillery fire.

b. Survive the counterbattery fire threat.

c. Provide ammunition on a timely basis.

To attain these objectives, a common philosophy was used for the two concepts developed in this class. First, in order to defeat the Soviet artillery, it was decided to fire either a combination of SADARM and ICM rounds or scatterable mines and ICM rounds. Since the targets are stationary, system response, TLE, and firing rates are not as critical as with other classes and concepts. In addition, extended range was used to set the battery back from the FEBA (out of range of Soviet artillery). As before, ammunition resupply was emphasized in order to speed the transfer of ammunition and to reduce the workload on the crews.

Based on the foregoing guidelines, the following battery concepts were developed:

a. Concept VA consists of a casemate SPH firing a volley of longer and heavier boosted SADARM and ICM rounds, a companion ARV, and a battery fire control vehicle integrated with FIST.

b. Concept VB consists of a casemate SPH with a larger cannon firing a volley of SADARM and ICM rounds, a companion ARV, and a battery fire control vehicle integrated with FIST.

The objective for these concepts was to develop a system optimized to provide counterbattery fire capability. As with other classes/concepts, results from previous and related system studies were reviewed and analyzed. This review indicated that increased counterbattery fire provides an operational payoff. One of the results seemed to suggest that if the US artillery could be isolated from Soviet artillery, it could successfully withstand its fire. Also, analysis indicated that as additional US systems are allocated toward counterbattery fire, exchange ratios are increased in favor of the US forces.

In order to develop an optimized system for counterbattery fire, information was required with respect to applicable targets, target acquisition, and command and control characteristics. In view of the short time frame for this study, limited information was obtained in these areas. With respect to the target, it was assumed to be a self-propelled armored howitzer in an 8-gun battery located within a 200-by 300-meter rectangle. It was assumed that the battery was located at the rear of region I and was a stationary target. With respect to US target acquisition and data transfer, it was assumed that target acquisition information came from SOTAS, fire finder, and other target acquisition equipment including FO. It was also assumed that the information would generally be provided by the tactical fire direction system (TACFIRE), via the command and control elements within the division, and eventually transmitted to the firing battery. Specific information on the presentation rate of the targets and the response characteristics outside the battery were not obtained. However, it is believed that the presentation rates would be lower than those used for the Class II and Class III concepts.

Concept development as related to battery functions was addressed to the following areas;

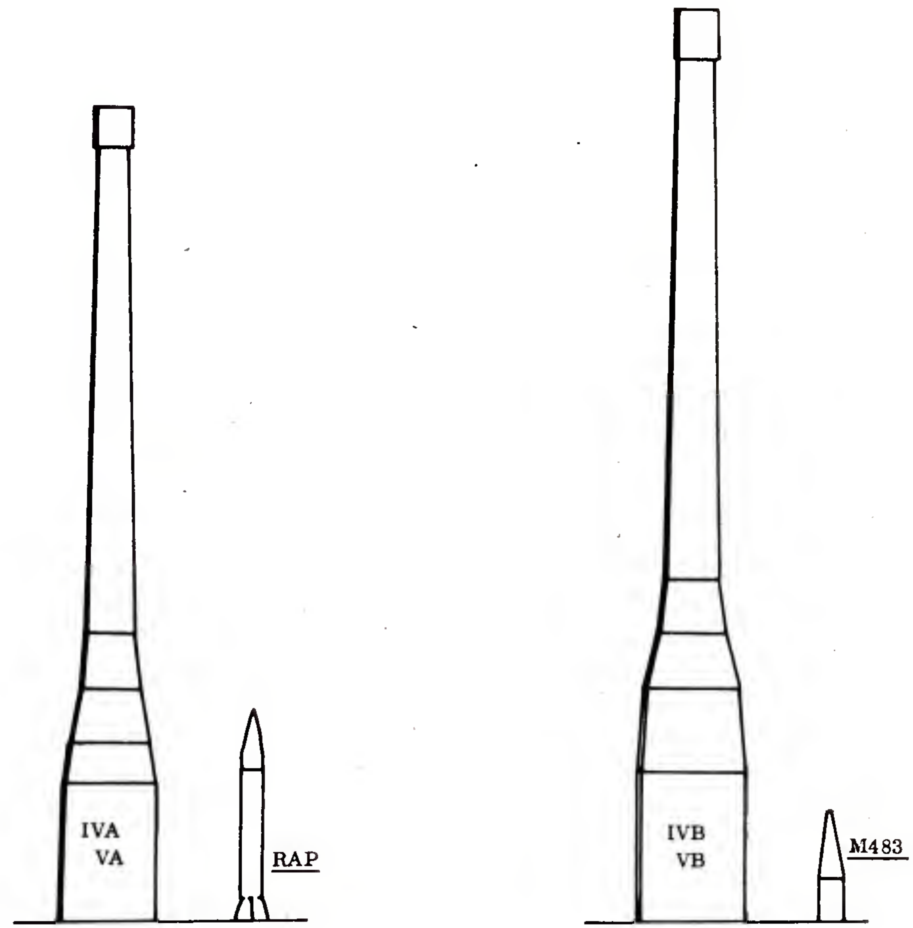
a. With respect to providing firepower, two possible munition combinations were considered; either a volley of spin-stabilized scatterable mine rounds with ICM rounds, or a volley of spin-stabilized SADARM rounds. It was assumed that the target presentation rate would be lower than with other concepts and that the targets would be stationary. However, there would tend to be more targets in each array. This would require massed fire and suggested that two or more weapons should fire at each target array.

b. With respect to providing a survivable battery, it was decided to use extended range in order for the weapons to set back from the FEBA out of range of most Soviet cannon. In addition, a shoot and scoot capability was provided, although it was assumed this would be little used.

c. With respect to supplying ammunition, it was decided to use tracked ARV and ammunition trucks.

In general, in synthesizing a battery for the counterbattery mode, it appeared that the role was less demanding at the battery level and that the battery would not differ significantly from those developed for the Class IV concepts. The major differences would be in those parts of the system which provided target information to the battery. (It appeared that the critical elements would be the target acquisition systems, communications, and data transfer.)

As a result of this study, two battery concepts were developed. Concept VA is similar to Concept IVA, and Concept VB is similar to Concept IVB. See figure 45 for a comparison of cannon and projectiles.




| | | | |
|---|---|---|---|
| M199 Cannon | 4850 lb X 270 in. lg | HTB III Cannon | 9200 lb X 300 in. lg |
| RAP Proj | 150 lb X 67 in. lg | Mod M483 Proj | 103 lb X 33.8 in. lg |
| Charge M31 | 29.15 lb X 33.4 in. lg | Charge M30A1 | 32 lb X 38 in. lg |

Figure 45. Cannon and Projectile Comparison (Class IV and Class V Concepts)

Class VI (Foreign Systems)

Background

Foreign SP 155mm weapon systems were evaluated as part of the ASES. Design and performance information was obtained through Data Exchange Agreements (DEA) and other channels. These data were reviewed in light of the ESPAWS requirements. Following are the subsystems which were considered.

SP70 - SP 155mm howitzer being developed by FRG/UK/Italy

GCT - SP 155mm howitzer developed by France

IFAB - FRG battery fire control vehicle

SOLTAM - SP 155mm howitzer being developed by Israel

BOFORS L50 - SP 155mm howitzer developed by Sweden

- SP 155mm howitzer developed by Japan

Each of the cited weapons has advantages and disadvantages. A limited review indicated that, as a first step in the evaluation, battery weapon systems using the SP70 and GCT should be generated. The following guidelines were followed:

a. Integrate the SP 70 into a battery similar to the Class I (baseline) concept with only minor changes to the SP 70.

b. Integrate the GCT into a battery similar to the Class I (baseline) concept with only minor changes to the GCT.

A comparative analysis of the GCT, SP 70, and M109A2 is given in table 31. Technical details of the SP 70 and GCT are given in the subsequent paragraphs.

SP 70 Self-Propelled Howitzer (Concept VIA)

General

The SP 70 (figure 46), is a tri-lateral development between FRG, Italy, and the UK. The design consists of a newly developed turret and chassis which incorporates Leopard tank chassis components. While the turret configuration is all new, the primary functional difference between the SP 70 and the M109A2 is automatic loading and the use of a flick rammer (for ramming the projectile into the cannon). The SP 70 Model A prototype was tested and apparently did not meet user requirements for high firing rates. A major redesign is under way to develop Model B which will

TABLE 31

Comparison of Data for GCT, SP 70 and M109A2

| | GCT | SP 70 | M109A2 |
|---|---|---|---|
| Combat loaded weight (tons) | 41 | 43.75 | 24.95 |
| Overall length (m) | 9.5 (1) | 10.2 (1) | 9.13 |
| Width (m) | 3.1 | 3.51 | 3.15 |
| Height (m) | 3.17 (2) | 2.88 (2) | 3.28 (2) |
| Ground clearance (m) | 0.43 | 0.44 | 0.45 |
| APU | 2.5kw/28vdc | 9kw/28vdc | None |
| Speed (kph) | 60 | 64 | 46 |
| Fording (m) | 2.2 (3) | 2.25 (3) | - |
| Range (km) | 450 (4) | 420 | 349.2 |
| Average rate of fire (auto) | 8 rds/min | 2 rds/min | N.A. |
| Average rate of fire (manual) | 1-2 rds/min | - | (4 rds/3 min) (1 rpm/1 hr) |
| On-board stowage (projectiles) | 42 | 30 | 36 |
| Barrel | 155mm/40cal/ bore evac | 155mm/39cal/ bore evac | 155mm/39cal/ bore evac |
| Resupply | (30 min/3 men) (20 min/4 men) | 4 rounds/min | - |
| Type of recoil | Independent - hydroneumatic - fixed length | Independent - hydroneumatic - fixed length | Independent - hydroneumatic - variable w/elevation |
| Burst rate of fire (rds/sec) | 6/45 | 3/10 | N.A. |
| Crew size | 4 | 5 | 6 |
| NBC | Positive pressure | Positive pressure | None |
| Recoil length (mm) | 950 | 700 | 914/609.6 |
| Rod pull (max) | $30 \times 10^4$N | $46.65 \times 10^4$N | $48.9 \times 10^4$N |
| Muzzle velocity (max) (m/sec) | 810 | 827 | 862.6 |
| Chamber pressure (bars) | 3,000 | 4,316 | 3,750 |
| Max ballistic range (km) | 23.5 | 24 (30 w/RAP) | 24 (30 w/RAP) |
| Travel lock | Remotely operated | Remotely operated | Manually operated |

(1) Tube pointed to the rear
(2) W/O machinegun
(3) W/preparation
(4) 40 km/hr average speed

Figure 46 SP 70 Self-Propelled Howitzer

provide burst and high firing rates. With respect to concept development as part of the ASES, the increased firing rate capability of Model B will be used.

The Leopard chassis is used without firing spades or lockout cylinders. A 35-hp engine provides auxiliary power. The main power plant is a 1000-hp, 8-cylinder, multi-fuel engine which provides a 20-hp per ton power-to-weight ratio. Following is the priority list for this weapon system.

a. Reliability

b. Effectiveness (accuracy, consistency, rate of fire reaction times)

c. Range

d. Mobility

e. Quantity of on-board ammunition

f. Protection and survivability

g. Traverse

h. Transportability

i. Storage life

Turret/Armament

The 155mm cannon is a new design having a slide block breech and is mounted in a conventional hydropneumatic recoil mechanism. Conventional elevation and traverse controls are used. The recoil mechanism is a constant length short recoil type as opposed to the variable length recoil type used in the M109A2 and, therefore, the SP 70 firing loads are higher. Apparently, the reduced recoil length is used to help achieve a lower turret height and silhouette. Aluminum armor is used, and it is slightly thicker than that on the M109A2. The standard turret ring of the Leopard tank is used and, as a result, the crew space is more confined than in the M109A2. It appears that the projected US family of projectiles could be fired from the SP 70. However, they would have to be fired using SP 70 propellant charges since US charges do not meet the stringent "residue free" requirements of the SP 70 sliding breech mechanism.

Automated Loading System

In order to meet the higher firing rates required by their user, an automated loading system was conceived for Model B. It is summarized as follows:

a. An external crane-like loader (figure 47) is used to pick up projectiles and lift them into the turret at a rate of four rounds per minute.

b. A projectile ready rack in the rear of the turret stores 32 projectiles in six bays (figure 48).

c. A hoist and fixed rammer (figure 49) receive the selected rounds from the rack and carry them to a transfer arm (figure 50).

d. The transfer arm moves the projectiles to the flick rammer.

e. The flick rammer rams the projectiles into the breech (figure 51).

f. The propellant charges are manually loaded (figure 52). Rounds can be fired either as loaded from outside the turret or from the ready racks at a rate of four per minute. In addition, a three round in 10 second burst capability is incorporated in the automatic loader. Figure 53 shows the crew positions and figure 54 shows the overall configuration for the shell handling system.

Fire Control and Communication Equipment

The SP 70 is intended to tie in with each of the developer nations' fire control equipment and procedures. However, in developing the ASES battery weapon system concept based on the SP 70, it was determined that US fire control equipment should be used. Therefore, this equipment would, in general, be similar to the M109A2 baseline system since relatively few changes would be required of the SP 70 to make it compatible with US FDC equipment.

NBC Protection

A positive pressure NBC protection system is incorporated into the SP 70. However, no additional individual protection is provided for crew members, nor are there any provisions to combat contamination introduced by projectiles, propellant charges, or any other item brought into the crew compartment.

SPH Crew Requirements/Functions:

Driver - Operates and maintains the vehicle.

Commander - In charge of communication, coordination, etc.

Layer - Operates fire control equipment.

Gunner - Loads propellant charges.

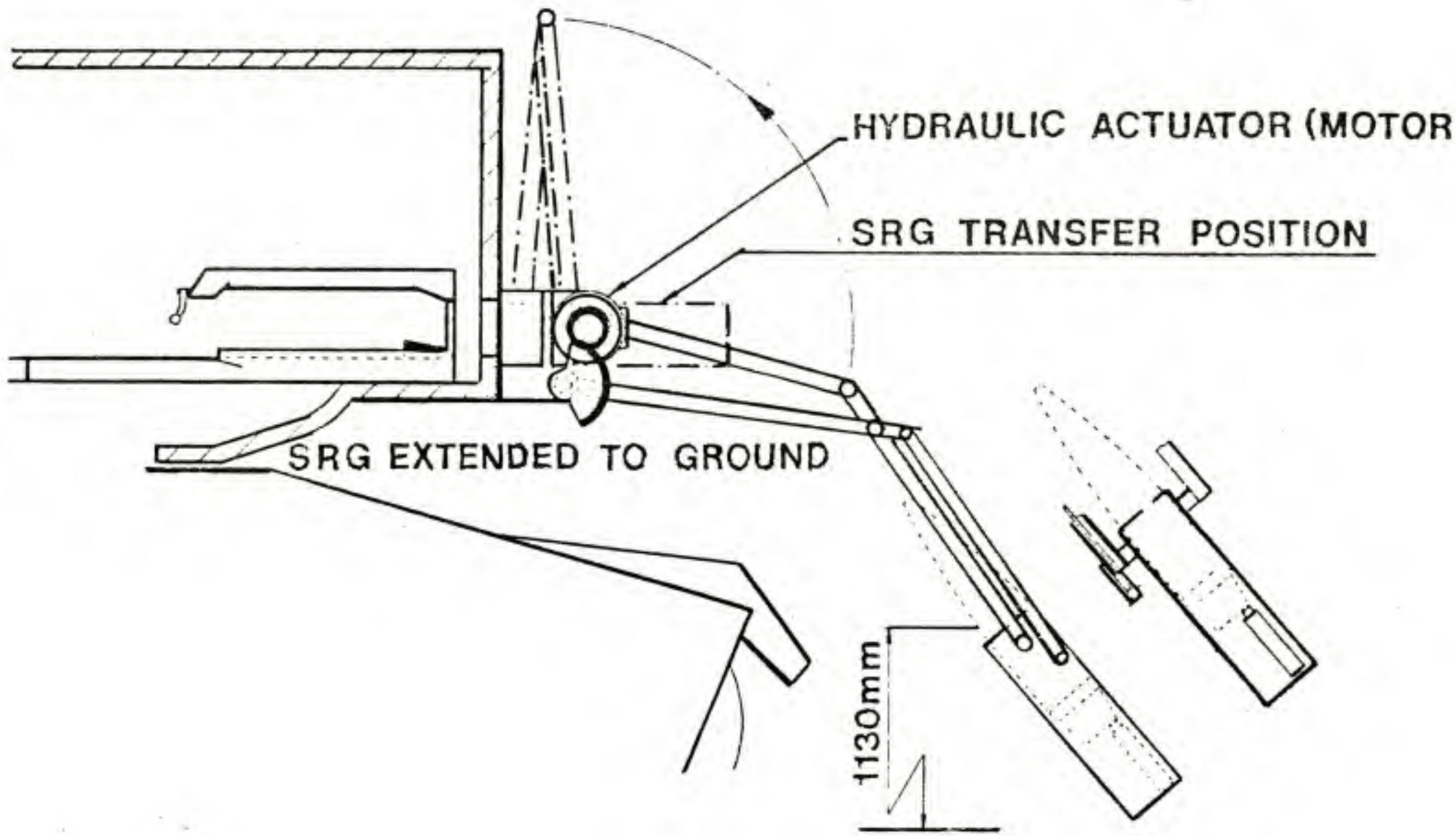



Figure 47 SP 70 Loader

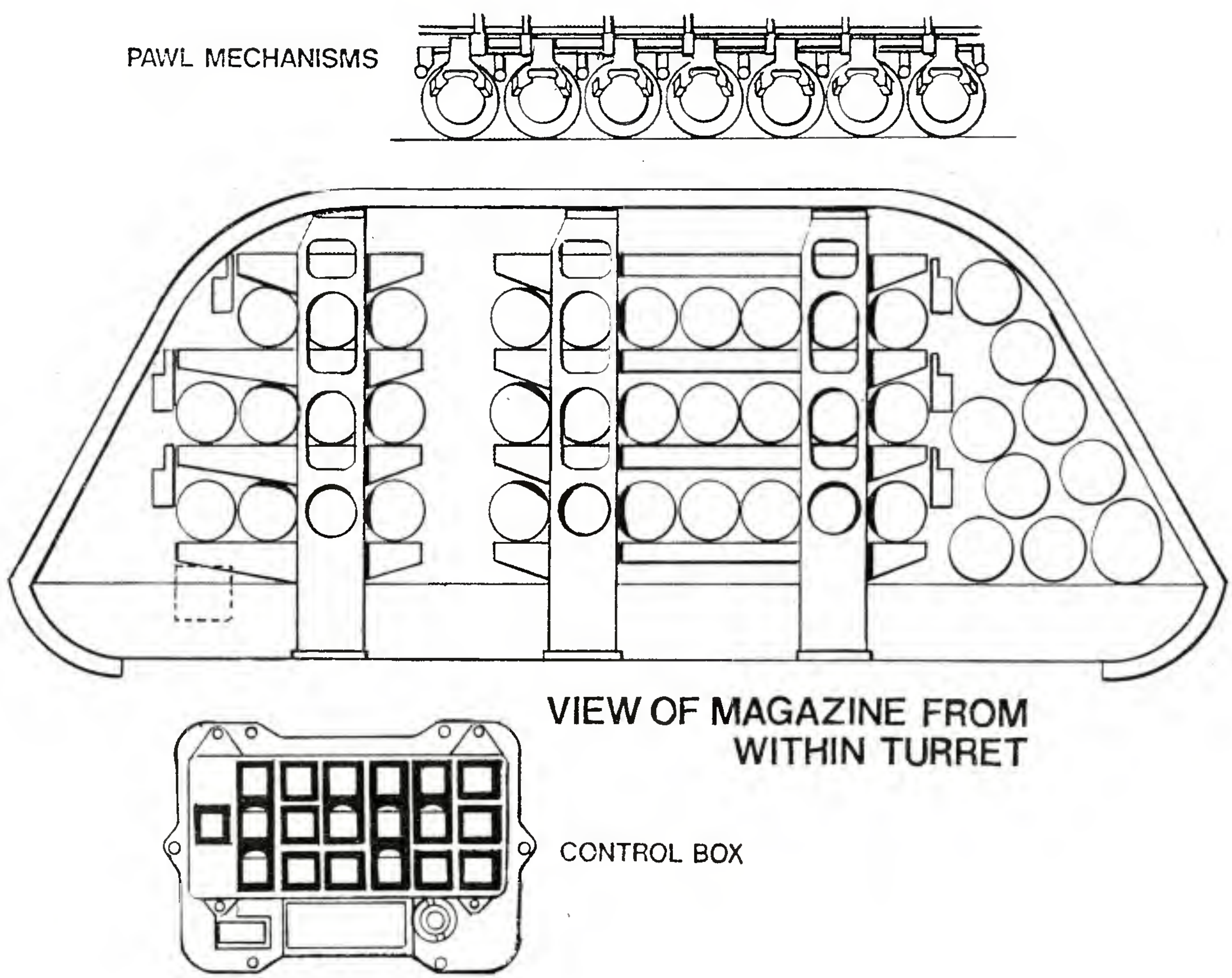



Figure 48 SP70 Ready Rack

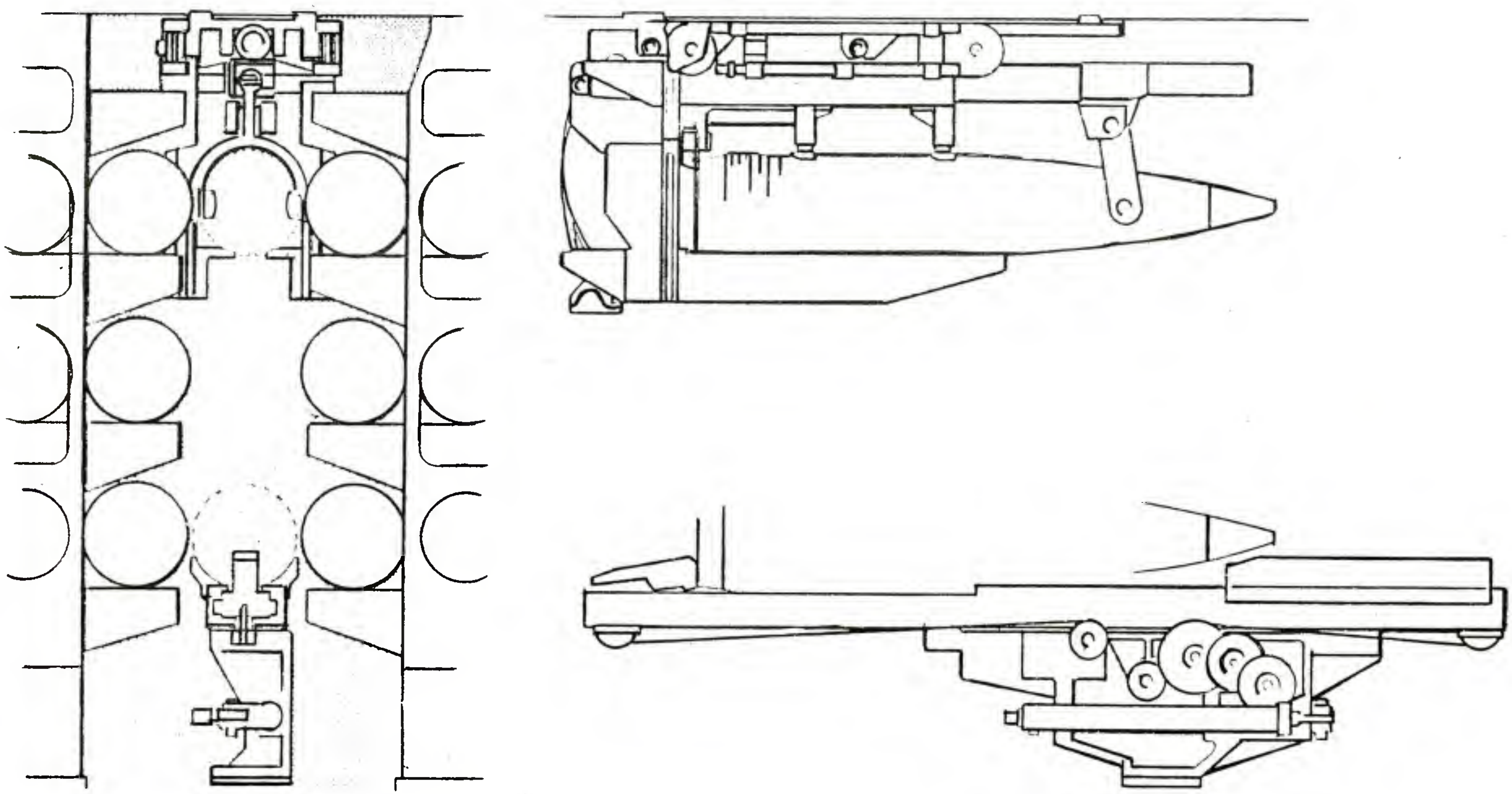


Figure 49 SP70 Hoist and Fixed Rammer

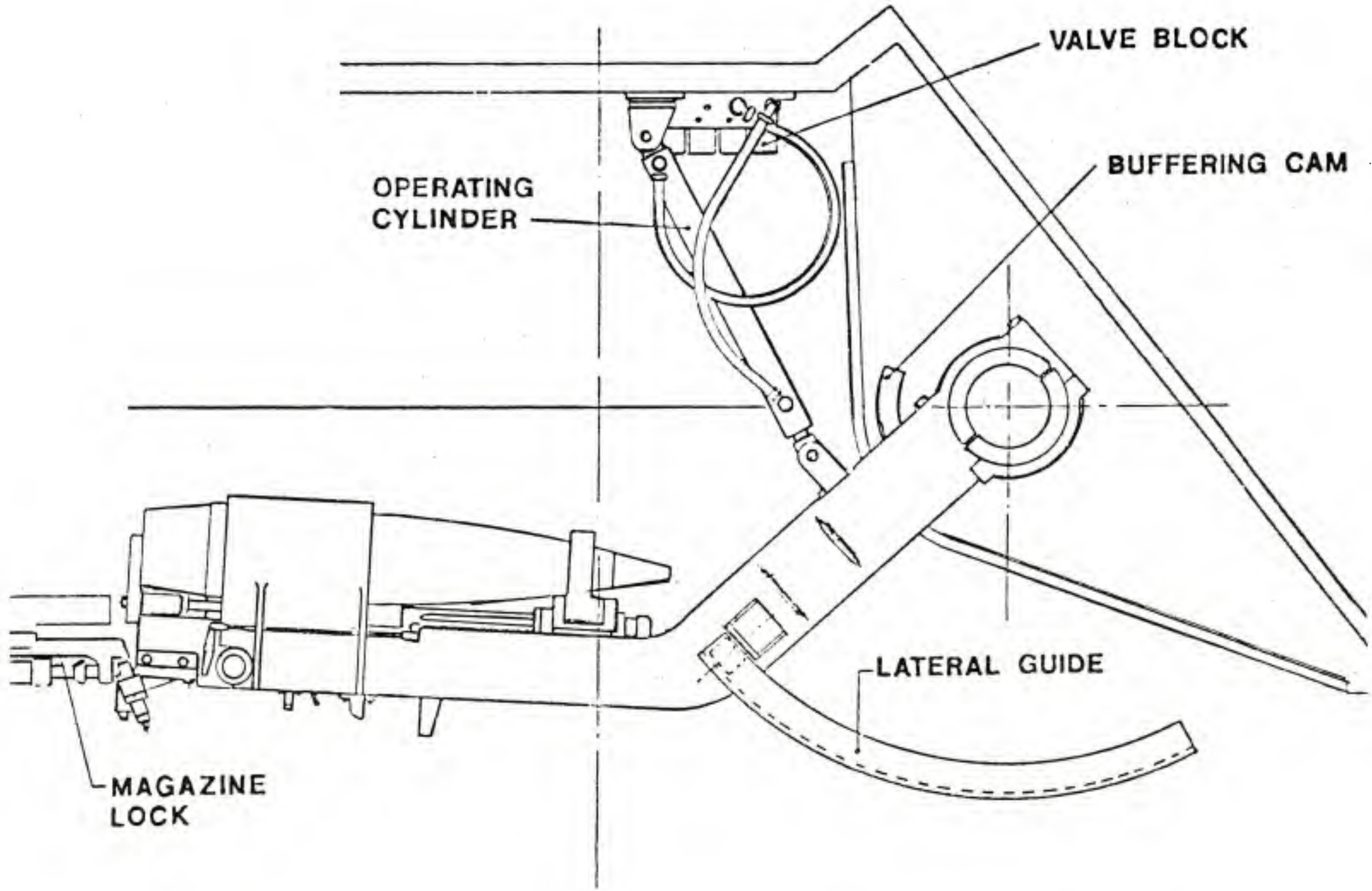



Figure 50 SP70 Transfer Arm

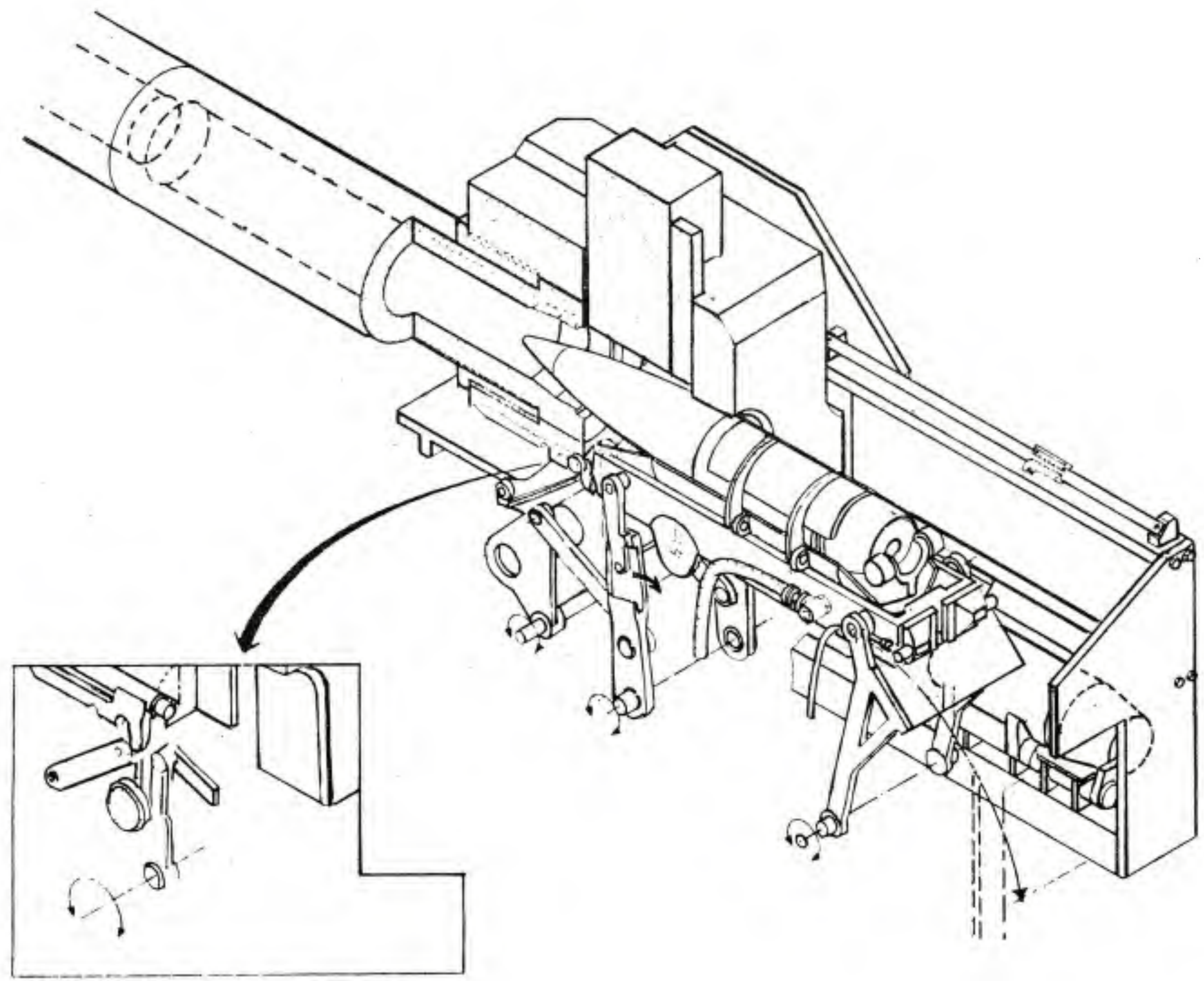


Figure 51 Ramming of Projectile (SP70)

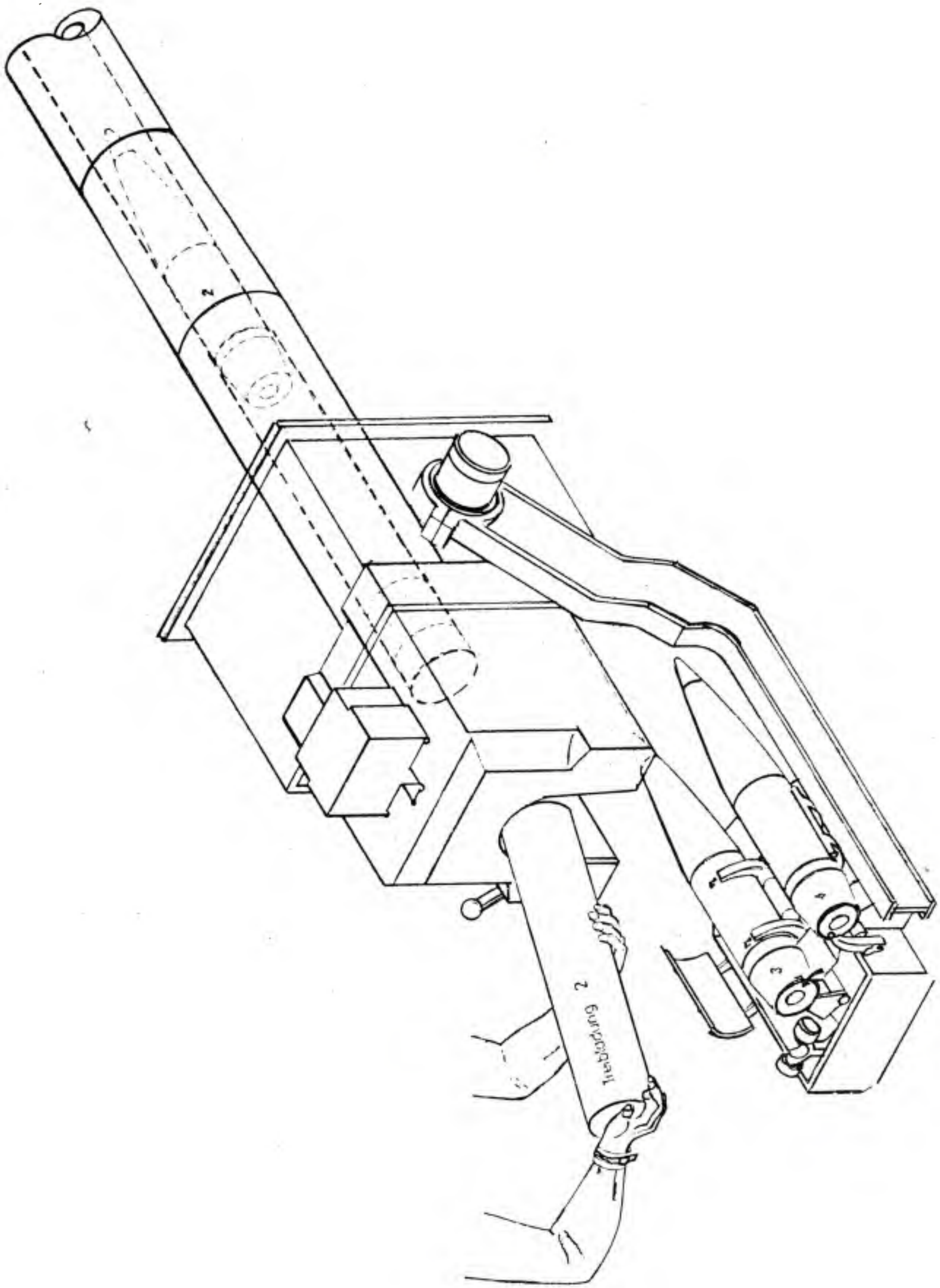



Figure 52 Loading of Propellant Charge (SP 70)

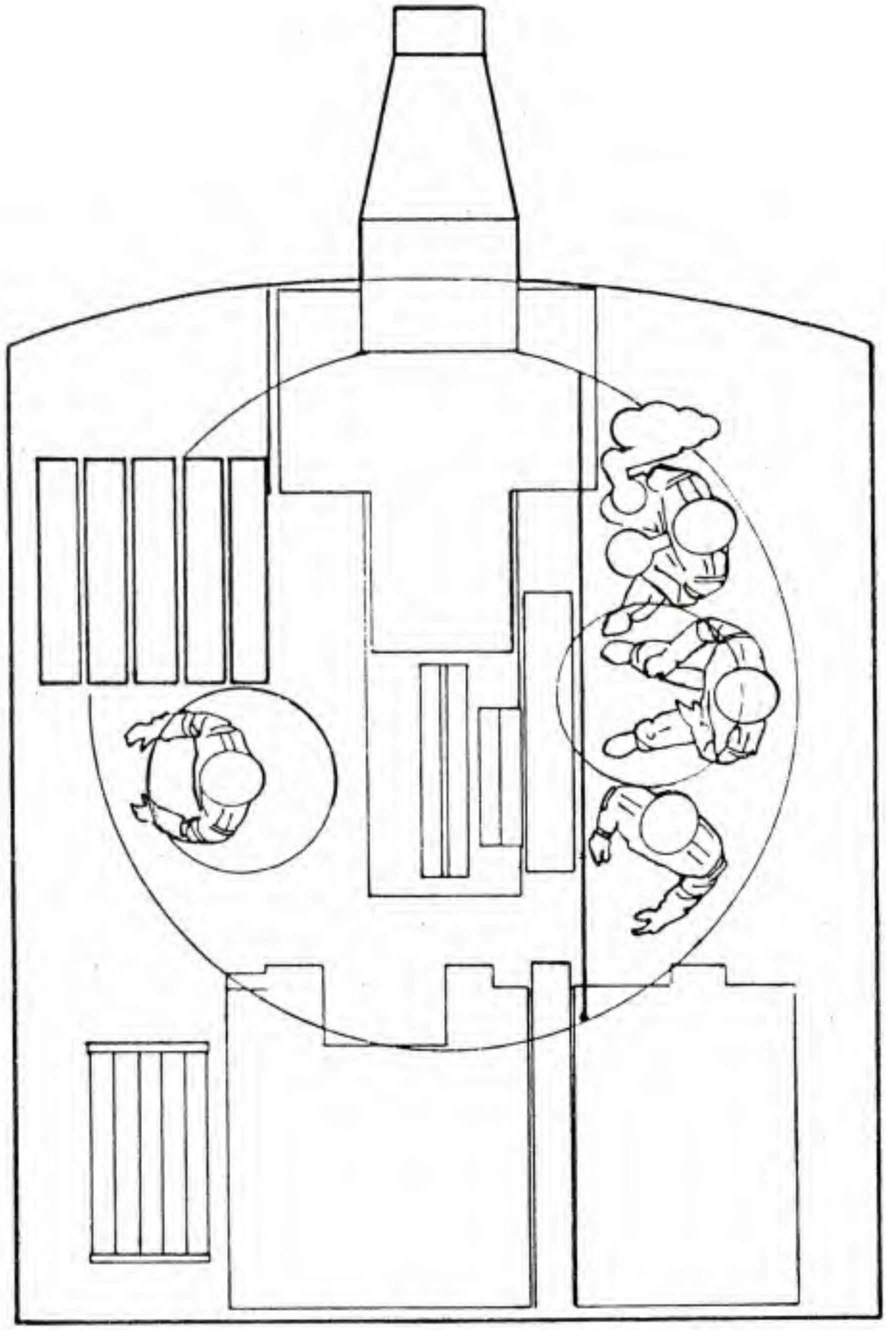


Figure 53 Crew Positions (SP70)

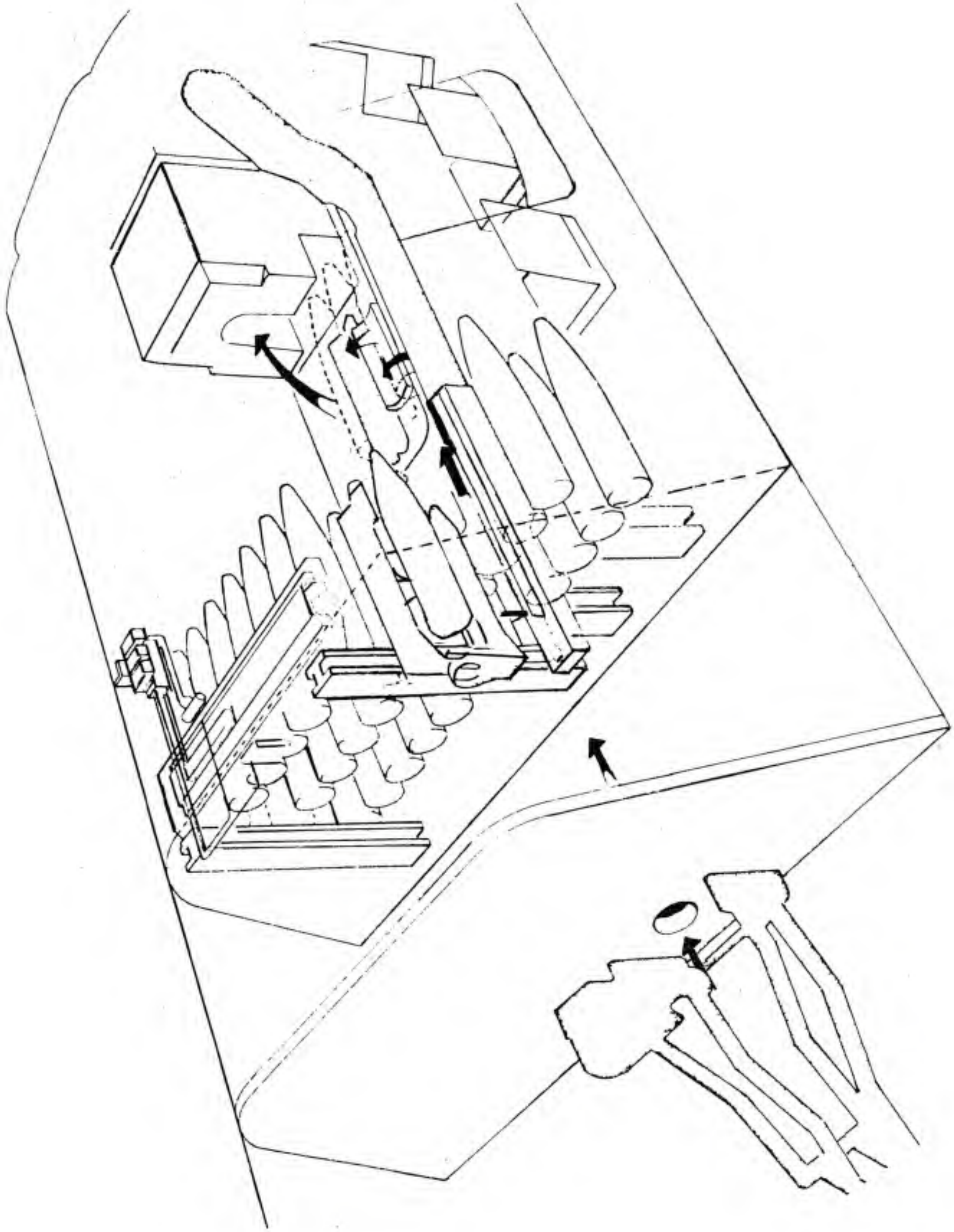


Figure 54 Shell Handling System (SP70)

Gunner - Operates the projectile magazine and rammer.

Ammunition Handling

It appears that the SP 70 could utilize the same ammunition handling system as the M109A2 baseline system. M813 ammunition trucks would transport ammunition from the ASP/ATP to the M548 ARV. The crane on the SP 70 could lift projectiles from the ARV or from the ground for insertion into the rear of the SP 70 turret.

GCT Self-Propelled Howitzer (Concept VIB)

The GCT consists of a newly designed armored turret mounted on an AMX tank chassis (figure 55). The chassis is used with minimal modifications and does not have a lockout suspension or rear firing spades. While it has an all-new turret configuration, the primary functional difference between the GCT and the M109A2 is automatic loading and ramming of the projectile and propellant charge for increased firing rates. Since the GCT is similar to the M109A2, the decision was to develop a conceptual battery weapon system using a slightly modified GCT, associated US equipment, and US projectiles. The GCT has essentially completed engineering development, and is now entering initial stages of production.

Turret/Armament

The primary weapon system utilizes a 40-caliber 155mm cannon with a sliding breech block. While it is not possible to explicitly determine that the GCT cannon is compatible with US projectiles, it appears that if it is not, only minor modifications would be required in order to assure that they could be fired. The projectiles would be fired using the sliding breech block mechanism and the French propellant charges in combustible cases, which are required for compatibility with the automatic loading system. The cannon has an elevation ranging from -5 degrees to +66 degrees and the turret is capable of traversing 360 degrees. The conventional hydropnematic recoil mechanism has a recoil length of slightly less than one meter. The turret has aluminum armor roughly equivalent to the M109A2.

Automated Loading System

In order to attain the firing rates required for the GCT, an automated loading system was developed. See figure 56. This consists of a ready rack built across the rear of the turret with 42 projectiles on one side and 42 combustible cartridge cases on the other side. The projectile feed mechanism uses 30 sequential steps to transfer, load, and ram the projectiles and combustible cartridge cases from the ready racks into the cannon. A separate feed mechanism withdraws the cartridge case from the honeycomb ready rack and loads it automatically into the cannon. A firing rate of six rounds in 45 seconds is the GCT requirement. This has been achieved. The cartridge case has been designed for compatibility with the loader and slide breech

Figure 55 GCT Self-Propelled Howitzer

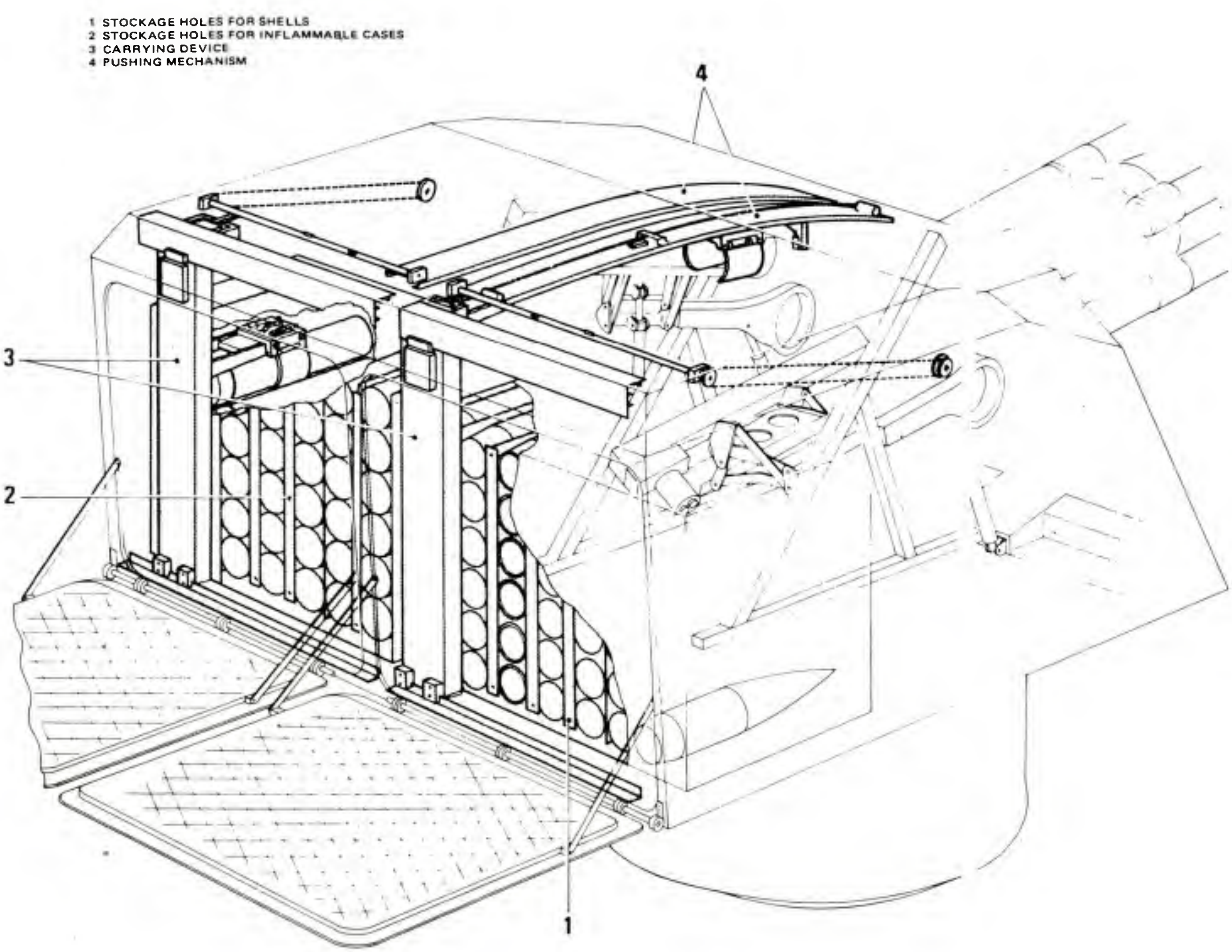



Figure 56 GCT Automated Loading System

block mechanism. It contains conventional bagged charges and has center core ignition. For all zones, a friction-fit disc is positioned on the top increment after the correct number of increments are in place. While residue from the cartridge cases was initially a problem it has been diminished by modifications to the case. In addition, an induction primer has been introduced following initial problems with a percussion primer.

Fire Control and Communication Equipment (Figure 57)

In some respects the fire control of the GCT is functionally similar to that of the M109A2 SPH. It consists of a panoramic telescope, a cant-correcting mount, firing display panel, and direct fire telescope. The firing data is transmitted via wire or radio, processed by computer, and digitally displayed to the crew. Data readout includes corrected traverse and elevation fire angles and propellant charge number. While the French initially accomplished some work in the area of automatic gun laying, the effort has not been pursued for the GCT.

NBC Protection

A positive pressure NBC protection system is incorporated into the SPH. However, no additional individual protection is provided for crew members, nor are there any decontamination alert devices in the event that contaminated projectiles, propellant charges, or other contaminated items are brought into the crew compartment. The over-pressure system is also used to exhaust residual propellant gases from the cannon.

SPH Crew Requirements/Functions:

Crew Commander - In charge of communication, coordination, etc.

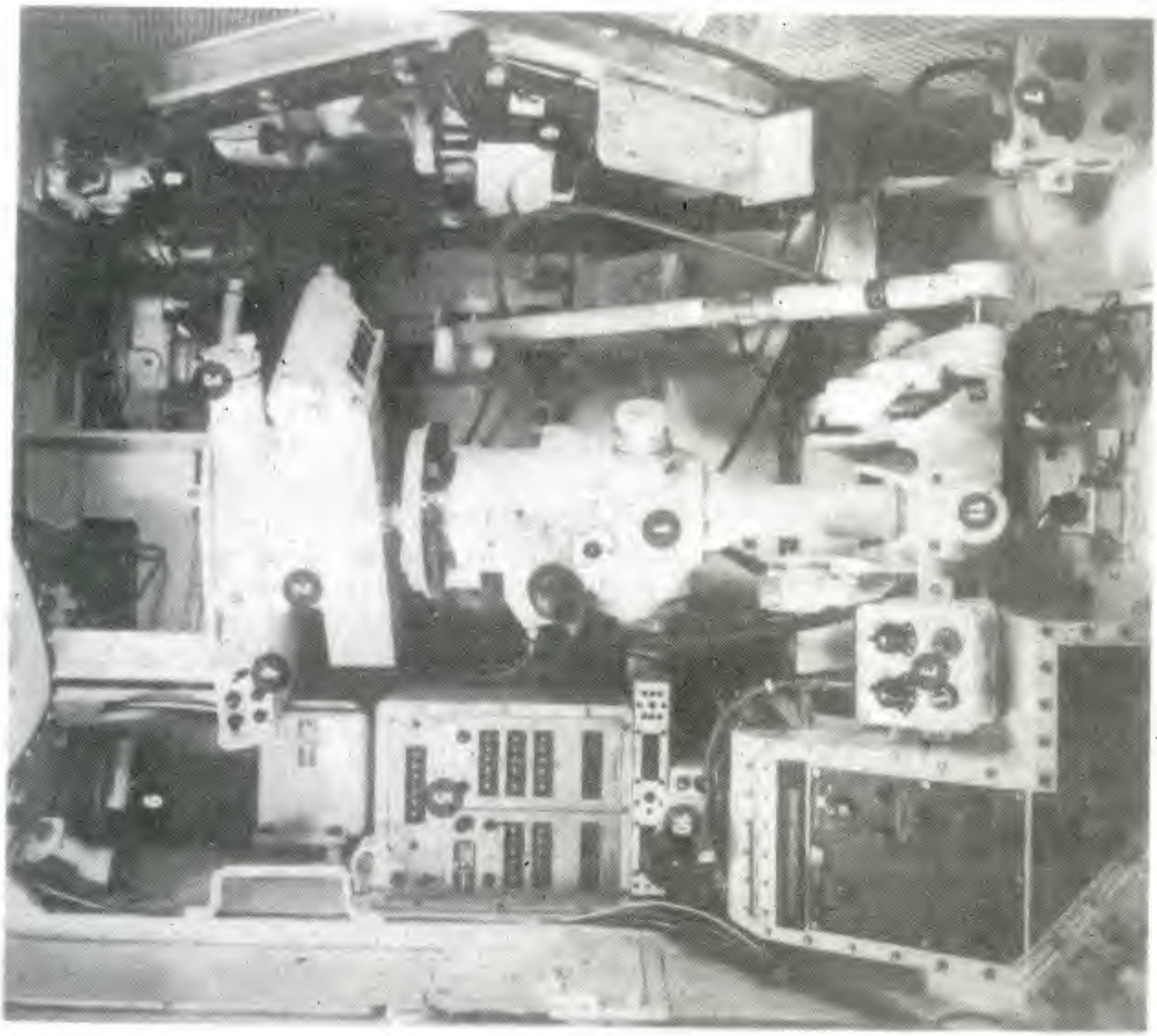
Driver - Operates and maintains the vehicle.

Gunner - Responsible for laying the weapon and operating fire control equipment.

Loader - Selects the projectile and charge to be loaded and prepares the cartridge case for proper zoning.

Ammunition Handling

It appears that the GCT could use the same ammunition handling system as the M109A2 baseline system. M813 ammunition trucks would transport ammunition from the ASP/ATP to the M548 ARV. The M548 would be backed up to the GCT and individual projectiles and propellant charges would be loaded by crew members into the ready racks through the back of the opened turret. Testing by France indicates



GUNNER'S POST

1. Opto-electronic goniometer
2. Traverse plate
3. Traverse sighting controls
4. Elevation sighting controls
5. Display console and computer
6. Rough sighting control
7. Radio-interphone control boxes
8. Emergency traverse sighting control
9. Emergency elevation sighting control
10. Direct fire telescope
11. Gimbal suspension of goniometer

Figure 57 GCT Fire Control and Communication Equipment that 42 rounds could be resupplied in approximately 20 minutes using a four man crew. This could be accomplished under firing or nonfiring conditions.

## Fire Control System Concept

### General

This section presents a comprehensive overview of the fire control, fire direction, command, and control and communications system devised to support the weapon systems study. In analyzing the various system concepts (II through V) it was concluded that the proposed fire control system could service any of the concepts. Those aspects of the system which are related to the weapon have been individually discussed under each of the concepts. However, in order to facilitate clarity and continuity of the discussion of the overall fire control system, a generalized version of the weapon associated fire control system is given in the following paragraphs.

### Proposed System

The proposed system will operate as follows:

a. Tactical fire control will be performed at the battery FDC.

b. Technical fire control will be performed at the weapon.

c. Each weapon will have automated gun laying and position location capability.

The rationale for the above is as follows: Rather then eliminate the battery FDC, it will be retained to provide the degree of management necessary to avoid confusion. Tactical decisions such as coordination, units to fire, method of fire, rounds to fire, and so on, will be retained at the FDC. It will have a computer, possibly a reprogrammed BCS or a BCS derivative, to automate these activities. The primary mode of operation of the battery after coordination with higher headquarters will be autonomous in that it will work directly with the FIST teams. The parent battalion will operate in a monitoring mode on a "silence is consent" basis. At the same time, the battalion will retain the authority to regain control of the battery as it sees fit for purposes of massing fires or prioritizing missions.

Technical fire control will be performed at the weapon. This is the logical choice when it is considered that most of the variables necessary for ballistic computations originate at the weapon, e.g., location, muzzle velocity, and propellant temperature. This approach avoids the unnecessary transmission of this data to the FDC only to have it returned a few seconds later in the form of firing data. Security and survivability are both increased by reducing the amount of communications time. Further, once an FDC assigns a mission to a weapon or weapons, all further communications can be between the weapons and the requesting FO thereby freeing the FDC for other missions. After completion of the mission, the weapons can notify the FDC that they are available for assignment to a new mission.

An additional consideration for justifying this capability is related to the automatically set fuze. If this device is incorporated in the overall systems concept and technical fire control is retained at the FDC, then after each shot, muzzle velocity measured at the gun must be transmitted to the FDC, where fuze time is computed, and transmitted back to the gun where it is then retransmitted out to a round which is on its way downrange. Assuming eight gun batteries, up to eight guns may be simultaneously trying to transmit muzzle velocities to the FDC, thereby further complicating matters and generating more "on the air" time with a resultant decrease in security and survivability.

An additional advantage of this concept is that, if necessary, each weapon has an autonomous fire control capability. That is, it is capable of working directly with a FO without the FDC. In effect, from a fire control standpoint, each weapon is a self sustaining entity capable of fighting to the last weapon.

In addition to the technical fire control, each weapon will possess a self location function thus providing the shoot and scoot capability essential to survival. Each weapon will also have an automatic laying capability which will eliminate human errors, reduce crew size, and optimize response time by permitting the weapon to operate at maximum speed.

### Hardware

#### Fire Direction Center

Tactical fire control will be accomplished within the confines of an integrated FDC based upon the MLRS vehicle. The FDC has a removable shelter (figure 17) configured to take maximum advantage of available space in the cargo bed. It will provide ballistic protection equal to or greater than that presently available in the M109A1 through the use of a minimum of 1 1/4 inches of aluminum armor. Additionally, it will provide an integral NBC protection capability in the form of an appropriate filtering system. This will allow the crew to continue to operate in an unrestrained manner in an uncontaminated environment. In the event of a puncture or failure of the filtration system, the crew is required to put on protective clothing and masks which are conveniently stored on board. This will also allow the crew to evacuate the vehicle in an NBC environment should the occasion arise.

Total power requirements for the system are estimated to be between 10 and 15 kilowatts. This includes simultaneous operation of the air conditioning and NBC systems. A turbine powered generator having a 35kw output and requiring a 24-inch by 18-inch by 18-inch envelope is currently available for this task.

The FDC will contain the following equipment which is directly in support of tactical fire control requirements:

a. Digital clock to indicate local time in the form of a date time group. The computer uses this information for inclusion in the record keeping process.

b. Communication security equipment to provide a means for the encryption/decryption of radio traffic, both voice and digital.

c. Computer display and terminal to accept and store fire missions and compose messages to the weapons. This will be the primary interface between the guns, the FO, and the battalion FDC.

d. FDO digital display (a remote display of the computer's display).

e. Radios for digital and voice communications (SINCGARS).

f. FDO electronic tactical display which will present real time information on the friendly and threat situation thus facilitating more timely decisions. In addition, this device will provide a digitizing capability to assist the FDO in selecting intercept points for moving target missions. It will display a 50 km by 50 km area to a scale of 1/50,000.

g. Headsets for each crew member to monitor the radio nets and the internal intercom. Each crewman will have the capability to select the net he desires through the use of a selector switch located at his work station.

h. Printer to provide hard copy of fire missions and overall conduct of the FDC.

i. Disc system for long-term storage of the data in paragraph h., above.

j. Land navigation system to provide grid location. This will be a low performance system to permit approximate location of the FDC since it is not critical to know its exact position. However, the FDC must know its relative location with respect to its weapons.

k. Electronic tactical display expander which permits the FDO to enlarge any section of the tactical display. The expanded section will be shown on a remote display and will provide greater detail then is possible on the 1/50, 000 scale tactical display.

1. Night vision devices for the driver and the FDO.

Technical Fire Control and Automatic Gun Laying System

Technical fire control will be performed at the gun. Gun-mounted ballistic sensors such as a propellant temperature monitor, muzzle velocity sensor, tube droop sensor, if required, and so on, will continuously supply data to the on-carriage ballistic computer on a real time basis. MET data, which is sent over a digital data link from the FDC, will also be automatically fed to the computer as will northing, easting, and altitude from an on-carriage position location system. The computer will send control data to the weapon's azimuth and elevation drives, the chief of section display, auto loader, and fuze setter.

In order to retain the rank and level of responsibility currently at the weapon, operation of the on-carriage computer will be transparent to the weapon crew, i.e., in response to a call for fire from the FDC, firing data will be automatically generated without any intervention by the crew. The system will be automatically capable of adjusting fire by communicating directly with a FO. However, the initial call for fire will always be through the FDC thereby maintaining the degree of control required.

The weapon will contain the following equiqment:

a. Ballistic computer which processes and disseminates data received from both on-and off-carriage I/O devices. Its primary function is ballistic computation.

b. Land navigator which determines weapon easting, northing, and altitude. Additionally, it provides gun tube azimuth data via its heading reference unit.

c. Gun sensors which supply the computer with the gun tube's elevation, and the pitch and roll attitude of the trunnion.

d. Propellant temperature monitor which supplies this data to the computer on a real time basis.

e. Gun drive controller which provides signals to the hydraulic gun drives for azimuth and elevation adjustment.

f. Autoloader controller which provides control signals to the autoloader.

g. Automatically set fuze controller which provides setting time to the fuze setter.

h. Chief of section display for all firing data. In an alternate mode, it will display diagnostic information associated with a built-in test routine. The display could be extended to remotely display the status of other weapon/vehicle systems such as engine and cannon temperature, fluid levels, etc.

i. Radios which transmit and receive both digital and voice data between the weapon and other links within the tactical and technical fire control loop.

j. Optical direct-fire sight which includes a rangefinder and automatic lead angle compensator.

k. Night vision devices for the driver and chief of section.

Typical Fire Mission:

1. FIST team chief issues a fire request via DMD to battery FDC. Battalion FDC monitors on a silence is consent basis.

2. At the battery FDC, the request is displayed on the computer's display and the target is indicated via a flashing symbol on the tactical display.

3. If the FDO requires more detail than is available on the tactical display, he moves a cursor over the area of interest by way of a joystick. The area within the cursor is then displayed in an enlarged format on the tactical display enlarger. This permits the FDO to make an immediate decision on whether or not to engage.

4. The FDO then looks at the computer's remote display and reviews the FIST recommended method of engagement. If he accepts it, he notifies the computer which sends the message to the guns. If he desires a change, he notifies the computer. The computer makes the required change and then transmits the data to the guns.

5. The computer composes and sends the message to the FO.

6. At the gun, the ballistic computer automatically calculates firing

data upon receipt of the computer's message. This data is displayed to the chief of section and places all systems in a ready mode.

7. Upon actuation of a single switch, the computer feeds the firing data to the weapon's controllers which in turn load, point, and fire the weapon.

8. Assuming an adjust fire mission and that the FIST chief had initially requested that adjustments be conducted through a FO, the weapons firing the mission switch over to the FO frequency and conduct all further actions through the FO.

9. Repeat step 7.

10. After proper adjustment, the FO requests FFE and the mission is completed.

11. The weapons report to the FDC that their mission is completed and that they are awaiting new assignments.

### Backup Capability

#### Fire Direction Center

If there is an equipment breakdown within the battery FDC, a manual capability will be available via the use of charts and a calculator. An alternate solution is to allow the battalion FDC to handle the mission. This would require some software changes to TACFIRE since it is not presently configured to work in this mode. An alternative is to bypass all FDC's and allow the FIST chief to work directly with the guns.

#### Weapon Fire Control System

If all or part of the weapon system should fail, it can operate with a reduced capability if it slaves itself to a properly functioning weapon by way of an umbilical cord. In this mode, it is in close proximity to the master weapon and can therefore use its firing data. The most difficult problem in addressing such alternate operating modes is arriving at an azimuth reference scheme should the gyro system fail. During daylight hours, with turreted weapons, the master weapon can azimuth reference the slave by providing it with a bearing to a distant aiming point. Once oriented to the aiming point, a turret ring azimuth scale can be used for shifts from that point. (This scheme obviously will not work for a casemate weapon.)

An alternate scheme, which will work with all concepts, is to mount on a surface of the master vehicle a reflector which is parallel to the gun tube. On the slave, a low-power narrow beam IR transmitter-receiver is mounted on a corresponding surface but on the opposite side of the weapon. It radiates perpendicularly to the gun tube. To orient the slave, it is parked next to the master such that light from the IR source falls on the mater's reflector. The slave is then rotated until the reflected beam falls on its receiver (at which time the slave is parallel to the master). This is the principal of collimation. The remaining constraint is that the slave must operate on relatively level ground since there is no provision for pitch or roll compensation.

## Antitank projectiles

### Background

Since a major mission of ESPAWS is to attack and destroy moving armored targets in region I beyond the FEBA, a critical parameter is selection of the antiarmor projectile. Inasmuch as the targets are moving at speeds of 5 to 15 km per hour, the synergistic performance of the fire control, weapon, and munition subsystems is of vital importance. Errors in location of the weapon, the FO, and the target, as well as random time delays, all tend to exacerbate the lead angle fire control computation. Currently, artillery fire control errors result in target location errors of 200 to 500 meters. Therefore, a current munition, such as Copperhead, has a foot print larger than several football fields.

HE and ICM rounds are of practically no use against moving armored targets since they have a minimal capability to destroy them. Analysis has shown that approximately 100 HE rounds or 50 ICM rounds are required to kill a stationary tank. Against moving targets, the potential of an HE or an ICM round is so low as to be unrealistic.

Early in the conceptual phase, a survey was made of potential approaches to attack moving armored targets. Given the fleeting nature of the targets, it became evident that primarily three types of projectiles offered promise of success. They are:

a. An area submunition projectile, such as a scatterable mine, designed and fuzed for instant activation after landing in the impact zone.

b. A guided round such as a passive IR CLGP.

c. A sensing round such as the milimeter wave SADARM.

The following paragraphs provide information relating to each of these rounds.

### Scatterable Mines

Previously developed scatterable mine rounds have been fuzed for barrier warfare, i.e., that of developing a barrier against tanks and armored vehicles before their arrival at the mined zone. While delivery rates and accuracy were not critical factors, this family of projectiles [referred to as family of scatterable mines (FASCAM)] provided a relatively quick means (in comparison with WWII technology) of disbursing mines. However, for the present concept study a slightly different approach was taken. The rounds must be delivered quickly and close to the moving targets. This leads to a requirement for an artillery registration adjustment system

(ARADS) or a HELBAT fire control, either of which can produce a TLE of less than 100 meters. In order to achieve the required submunition density, each round should contain 10 mines (base ejection) with each mine fuzed for instant activation. A volley of 15 rounds should be fired. Given this density, there is nearly a 100 percent probability that a moving tank would encounter a mine within 100 meters of travel, and a near unity probability that a mobility kill or a firepower kill would result.

Passive IR CLGP

Currently, Cooperhead uses bagged charges and has a range of 16 km. A mid-course guidance capability referred to as "Fly Under, Fly Out" (FUFO) provides a means to increase the range and to provide better performance under low cloud cover conditions. During the terminal phase, semiactive laser guidance is used to home on the target. The warhead consists of multiple HE shaped charges.

While an extensive system analysis for a passive IR seeker for a CLGP has not been accomplished, components have been evaluated and it appears that passive IR guidance can be developed. The initial study has centered on using a technological approach based on the hostile weapon location system (HOWLS) IR seeker and development of a discrimination algorithm and background characterization. This sensor is a two-color mercury-cadmium-tellurium IR device.

With this system, while other approaches are possible, it appears that a tank, such as the Soviet T-62, would provide a signature ranging from a maximum of approximately 5 degrees C $\Delta t$ to a minimum of 2 degrees C$\Delta t$ under the following conditions: 10 to 13 um wave band; 1 km range; 2 mrad instantaneous field of view (IFOV); 20 degree depression angle. (As rounds come in at higher angles of fall, the IR signal improves.) When using sensors with this small IFOV, they must be scanned to achieve a total field of view (FOV) compatible with target location errors. However, for a 2 mrad IFOV, the signal-to-clutter ratio is the limiting factor, not IR sensor sensitivity. Separate tests and analyses have indicated that a 1 mrad sensor will meet the required signal-to-clutter ratio of 2 under the following conditions; 20 degree dive; 1 km range; all azimuth angles; 2 degree C $\Delta t$.

Since target acquisition may occur only 1.5 to 2 km from target impact, scanning seekers require high scan rates. Concepts have been theorized with maneuverability and seeker footprints having radii as large as 100 meters and which are compatible with scanning seekers. Reducing the TLE to less than 100 meters with advanced ARADS or HELBAT fire control techniques will have an obvious benefit in reducing scanning and maneuvering requirements for a passive IR CLGP, and in improving performance under low cloud cover conditions.

Sense and Destroy Armor (SADARM)

Recent advances in electronics, sensors, and warhead technology have led to a new munition system concept, known as SADARM, which will have increased effectiveness against point targets. In this concept, the round is fired toward a predicted target area. As the projectile approaches that area, submunitions are ejected and individually deployed by vortex-ring parachutes into a spinning descent while circularly scanning the ground for targets. When a target is sensed, the submunition's self-forging fragment warhead is automatically fired. While sensor sensitivity and warhead range currently limit the "basket" size to a radius of approximately 80 to 100 meters, recent advances in fire control technology, if incorporated into the overall ESPAWS concept, could make SADARM an effective point target munition.

## Ram Considerations

### Background

While RAM could not be assessed during the initial ASES design concept, it is an important consideration for tracked vehicles in general and for SP artillery in particular. As an example, it is well known that RAM factors for tracked vehicles are considerably lower than for wheeled vehicles. Although RAM problems for the M109 are difficult to assess with accuracy, a recent sample data collection report published by ARRCOM indicates that for the M109A1 the mean rounds between failures (MRBF) is 725 and the mean miles between failures (MMBF) is 180. These figures include both random failures and failures resulting from personnel not following prescribed maintenance and operating procedures. Twenty-six percent were attributed to personnel error.

The M109 failures involved the following subsystems: electrical, cooling, fuel, engine, turret, recoil, and cannon. The M109 results are similar to those for the M107 and M110 families which had MRBF values ranging from 245 to 445, and MMBF values ranging from 165 to 210. Also, a significant percentage of these malfunctions were due to personnel neglecting to follow prescribed procedures. As with the M109, hardware failures occurred in both turret and chassis subsystems. To summarize, following are the key points:

1. The MRBF and the MMBF are undesirably low in view of the high firing rates and the long travel distances required during a typical day on the battlefield. While the availability was fairly representative, this was probably due in large part because the SPH were at Ft. Sill which has extensive shop facilities. When considering the facilities available under battle conditions, much lower availability values should be anticipated.

2. The RAM problems are not concentrated in any one area, are distributed among the turret and chassis components, and are due in

significant measure to human error.

Another problem surfacing within the Army is a decrease in the mechanical know-how of recruits coming into the maintenance organizations. In past decades, recruits tended to have mechanical backgrounds and thus came into the Army with an inherent capability. Current recruits have less native ability. Associated with this problem is the development and use of much more complex weapon systems. As a result, we have a potential dichotomy where weapon systems will be more complex while maintenance personnel will have less background and aptitude to maintain the new equipment.

For a number of years, TARADCOM has had a program to improve the RAM of tracked weapon systems. This has been oriented toward developing techniques and materiel to reduce the workload of maintenance personnel and to decrease the skill levels required to test and diagnose problems; also, to evolve indicators of what needs to be done to overhaul or repair a vehicle before it breaks down. The fruition of this program will encourage maintenance personnel to use preventive maintenance as a means of increasing the availability of weapon systems. These studies have shown that performing maintenance with current equipment and procedures results in the following problem areas:

Late detection of faults

Faulty diagnosis

Inefficient fault isolation

Low mechanical productivity

Excessive rework

Insufficient maintenance

While exact causes are hard to identify, it is known that diagnosis of problems in tracked vehicles is extremely difficult and borders on being beyond the capability of the maintenance crews. In large part this may be due to current test equipment which is not diagnostic but merely indicates voltage and pressure values. As a result of this difficulty in diagnostics, whole engines may be replaced when all that may be required is a clean fuel filter or an increase of compression in one or two cylinders. This kind of problem occurs throughout the weapon systems and the true operating capability of individual electrical, mechanical, and hydraulic components cannot be realized unless a skilled mechanic uses the preferred test equipment and follows all the maintenance instructions available to him.

Preventive Maintenance Approach to Achieve Better RAM

The TARADCOM program is providing improved techniques to significantly increase the availability of weapon systems. The initial phase of this program is referred to as simplified test equipment for internal combustion engines (STE/ICE). Under development is a tester for internal combustion engines which reduces the skill level required to maintain engines and, at the same time, provides indications on the actual operating condition of many parts of the power train. Figure 58 shows this new tester on the left, and all of the equipment it replaces on the right. It is attached to the vehicle by an umbilical cord and measures maximum and minimum values such as:

Battery and regular voltages

Engine rpm during cranking and running modes

Battery and starter circuit resistance

Based on these minimum and maximum values and their rates of change under controlled conditions, output information is provided on such parameters as:

Battery charge

Operating condition of other electrical components such as the starter, regulator, and alternator

Engine performance including such parameters as compression unbalance and percentage of power available

Digital readouts indicate whether individual components are operating within desired ranges and which components, if any, need replacement.

While the STE/ICE program is currently oriented toward the power train, additional programs are under way to expand the concept to other subsystems. The STE/T is a transition program to expand diagnostics to turret systems. A follow-on program, STE/X, will provide second generation equipment for combat vehicle forward support. Figure 59 summarizes the first and second generation systems.

A preliminary analysis was performed to determine how the use of STE/ICE could impact the automotive reliability of the M109A1 system based on information considered in the ARRCOM sample data collection program. The following assumptions were made:

a. Organizational senior NCO inspectors would perform STE/ICE tests at prescribed intervals.

b. Maintenance requirements identified by the tests would be performed.

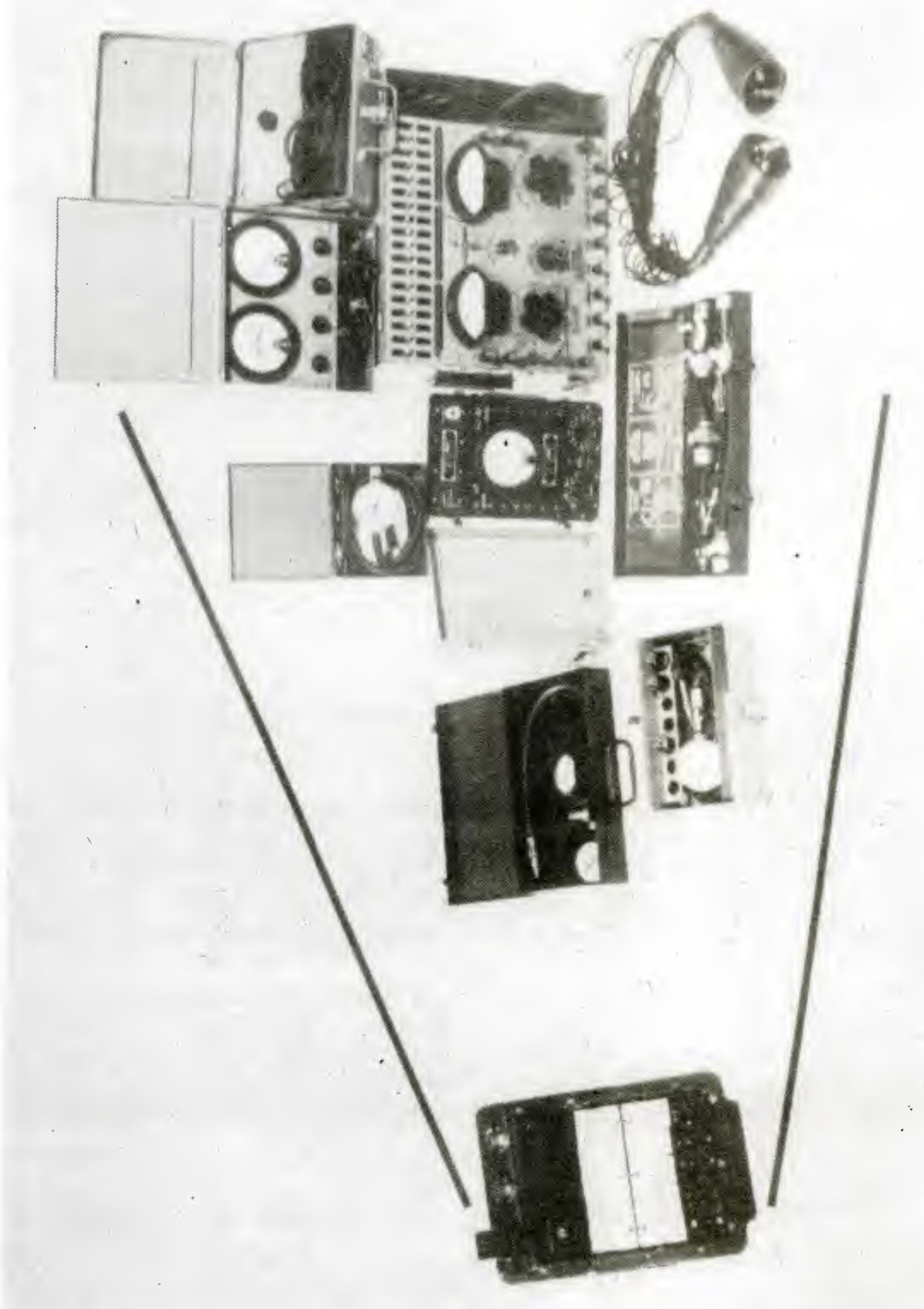


Figure 58 Engine Tester

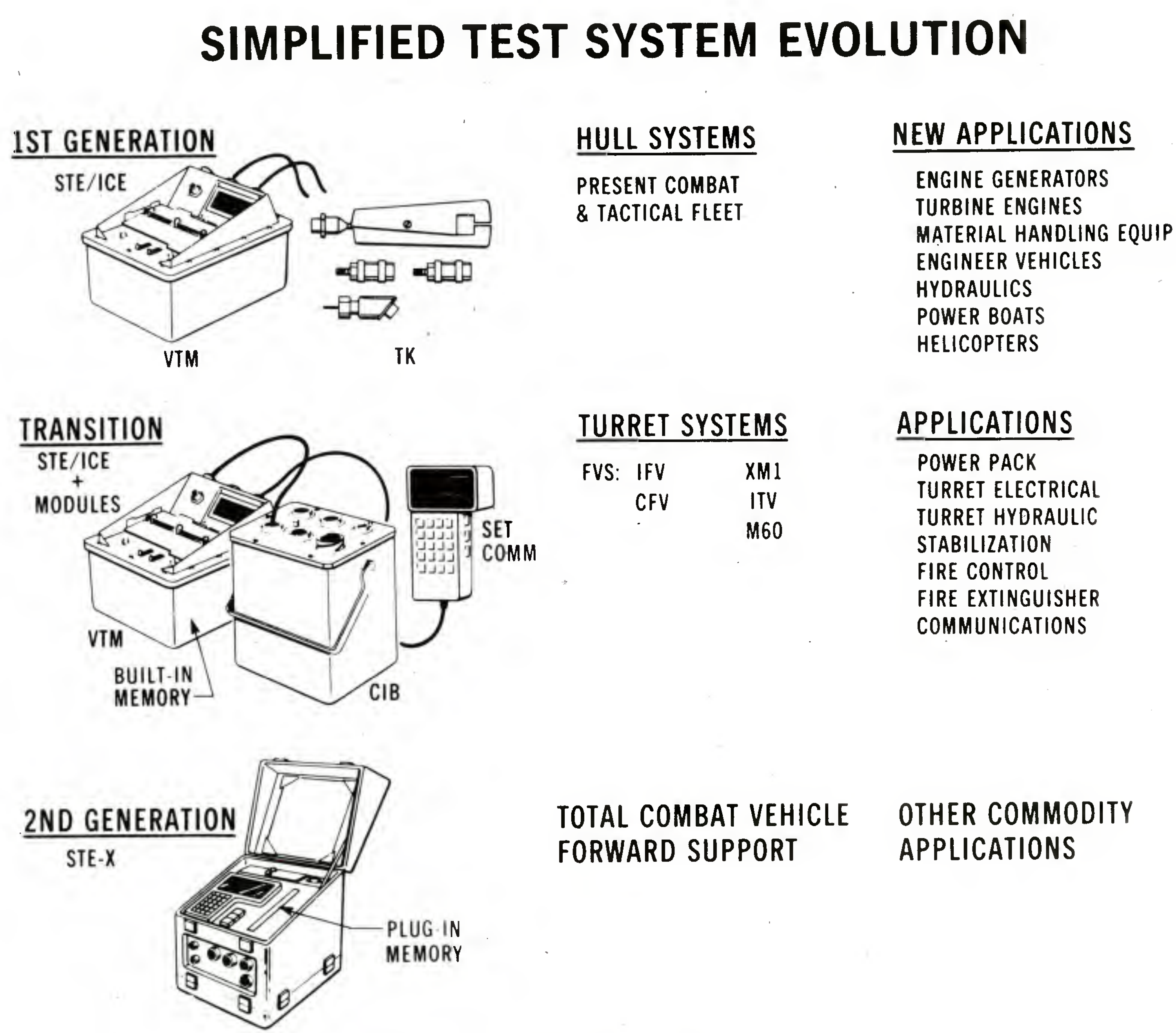



Figure 59 System Testers

c. All STE/ICE diagnosable failure incidents listed in the sample data as the result of deficient maintenance would be eliminated.

d. Fifty percent of hardware-prompted failures which are diagnosable with STE/ICE would be eliminated.

Based on these assumptions the following data were extracted from the tables of significant repetitive failures contained in the ARRCOM report.

a. Automotive deficient maintenance failures (total 86) which could be eliminated by use of STE/ICE --------------- 47

b. Automotive hardware failures (total 389) which could be eliminated by STE/ICE ----------------------------- 87

c. Total failures eliminated with STE/ICE ---------- 134

d. Total repetitive automotive failures ------------ 475

Failed parts which were considered STE/ICE diagnosable were starters, generators, regulators, batteries, and engines. Elimination of 134 out of 475 repetitive failures equates to a 28 percent reduction. When this is converted to MMBF improvement, the M109A1 which presently attains 180 MMBF would achieve 249 MMBF. This analysis was possible because approximately half of the automotive failures were repetitive. Repetitive failures are easily placed into two categories; those diagnosable under STE/ICE, and those not diagnosable. In the turret and arament areas only 10 percent of the failures were repetitive, and none were considered diagnosable with STE/X (the second generation tester incorporating all turret diagnostics). Future SPA will probably be equipped with much more electronics and more sophisticated hydraulic subsystems. From a subjective viewpoint, STE/X could provide the necessary diagnostic capability to obtain improved RAM in spite of the higher complexity.

In summary, STE/ICE and STE/X could provide at least a 28 percent reduction in combat abort automotive failures, and could compensate for higher complexity in the turret, armament, and fire control subsystems. The analysis centered on reducing the number of repetitive failures, and since the ARRCOM report has a limited time frame for data collection there is a built-in limitation on how much RAM increase can be provided. If, as the ARRCOM program continues, it identifies more of the failures to be repetitive; then subsequent analysis will probably indicate that the STE/X approach will have greater potential to increase RAM.

Multiplexing Approach to Achieve Better RAM

General

Tanks, APC, and SPH have all followed the same trend in achieving greater performance. The distribution of electrical power has led to complex, bulky, and trouble-prone wiring harnesses in turrets and chassis. Recently, TARADCOM has started a program to develop multiplexing technology for Army tracked vehicles. In general, TARADCOM using technology which has been developed and widely implemented in the Aerospace industry. This Army program is referred to as advanced techniques for electrical power management, control, and distribution systems (ATEPS). It was initiated in 1975, and has progressed to prototype hardware development.

Multiplexing is a time-sharing process where a single bus cable will, as shown in figure 60, simplify bulky vehicle harnesses and significantly reduce interconnecting wiring. Through the use of advanced signal processing and remote terminals (junction boxes) at assorted distribution points, techniques are available to reduce electrical wire footage by factors of two or more and to obtain advantages of redundancy, simplicity, and reduction of components to achieve dramatic increases in RAM values for Army tracked vehicles. Figure 61 shows a representative design using multiplexing for tank applications. Shown at the bottom is a single circut for the chassis with typical remote terminals and displays for the driver. Shown at the top is a single bus cable for the turret with remote terminals and displays for the gunner and commander. The remote terminals contain the electronics necessary to interface the bus cable with the equipment (components) and the equipment with the bus. They convert signals for transmission to the bus controller, and also decode data from the bus controller. The solid state switches required to connect power to the equipment are also located in the remote terminals. The bus controller contains a microcomputer memory for the bus cable. The programmable microcomputer executes stored programs, maintenance programs, and self-test routines.

Application for SPH

A concept study has been initiated to adapt the ATEPS technology to SPH. The investigation has emphasized commonality with other combat vehicles, and the methodology has progressed as follows:

Data collection

Object suite formulation

Signal list formulation

ATEPS hardware assessment

Computer aided analysis

System synthesis

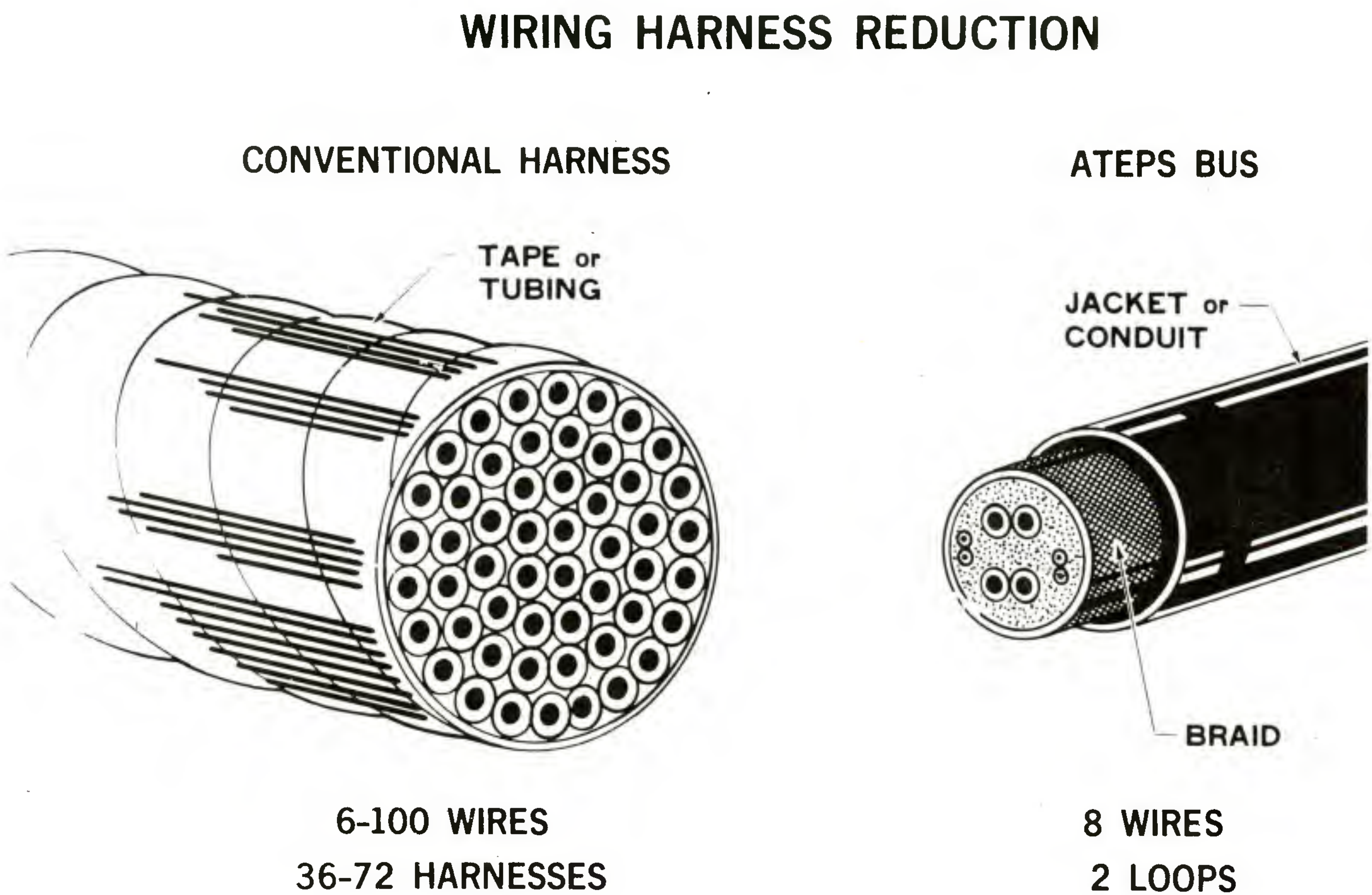



Figure 60 Conventional Wiring Harness Versus ATEPS Bus Cable

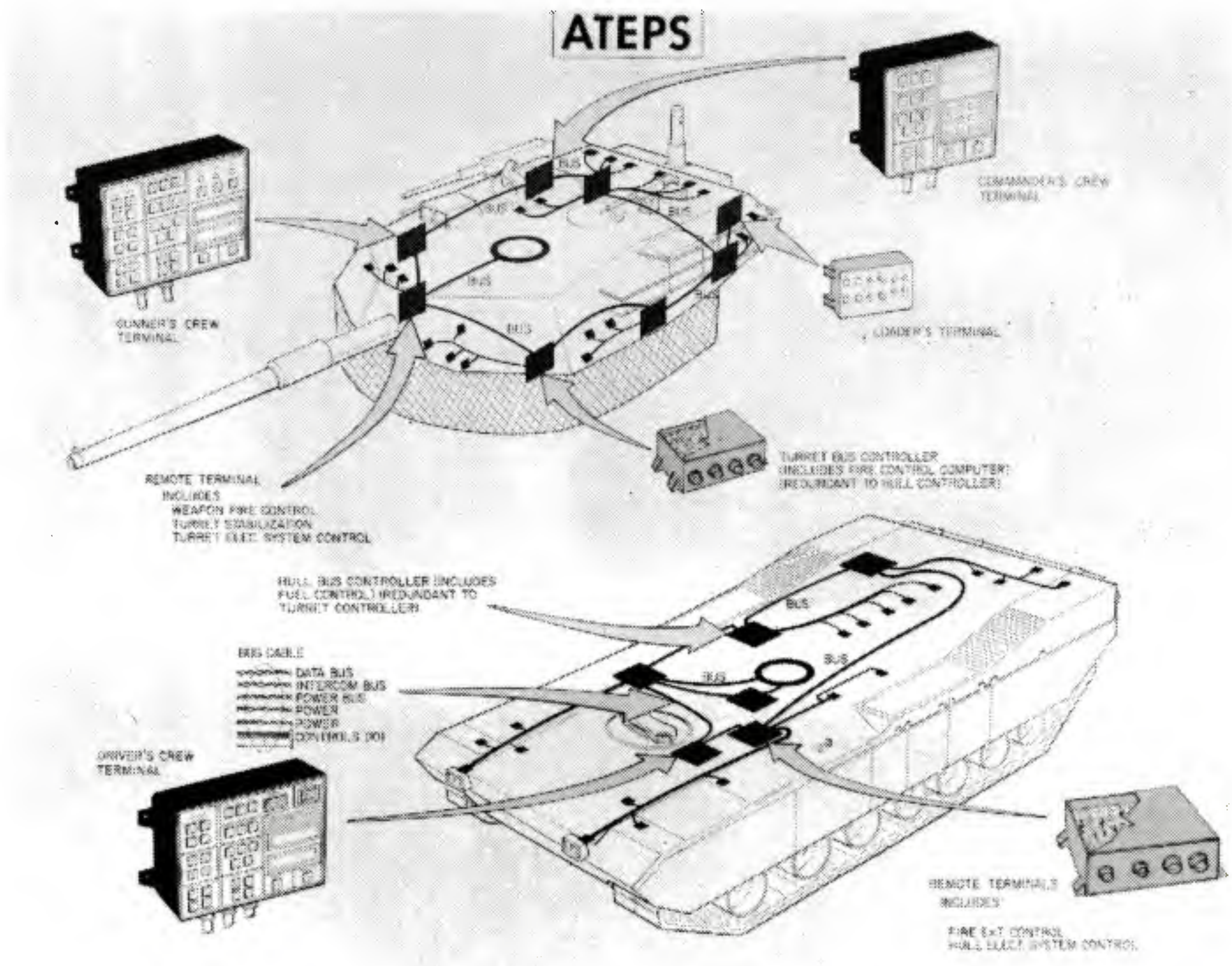



Figure 61 Application of ATEPS to a Turreted Chassis

Effectiveness evaluation

The results of the investigation indicate there is a high potential for multiplexing to increase the RAM and to improve the electrical distribution system in SPH. Figure 62 shows a block diagram for the system and figures 63, 64, and 65 illustrate possible terminal designs for crew members. The driver's terminal in figure 65 is being fabricated for an XM1 tank prototype demonstration in FY 80.

The following summarizes the communication capabilities:

| Media | Communication with |
|---|---|
| Radio | TACFIRE |
| Wire | FO and infantry units |
| | Aircraft |
| | Other ground vehicles |
| **Modes** | **Types of data** |
| Secure digital data | Command and control |
| Secure digital speech | Maintenance |
| Normal speech (audio) | Logistics |

Input/output equipment

- ATEPS crew station
- terminal message
- entry and display
- Normal Audio

The data processing philosophy is as follows:

Distributed

- Each subsystem has its own internal microcomputer(s)
- Each subsystem performs its own subsystem-peculiar computations

Centralized bus control computer

- Controls flow of information on ATEPS data bus
- Solves power control logic equations

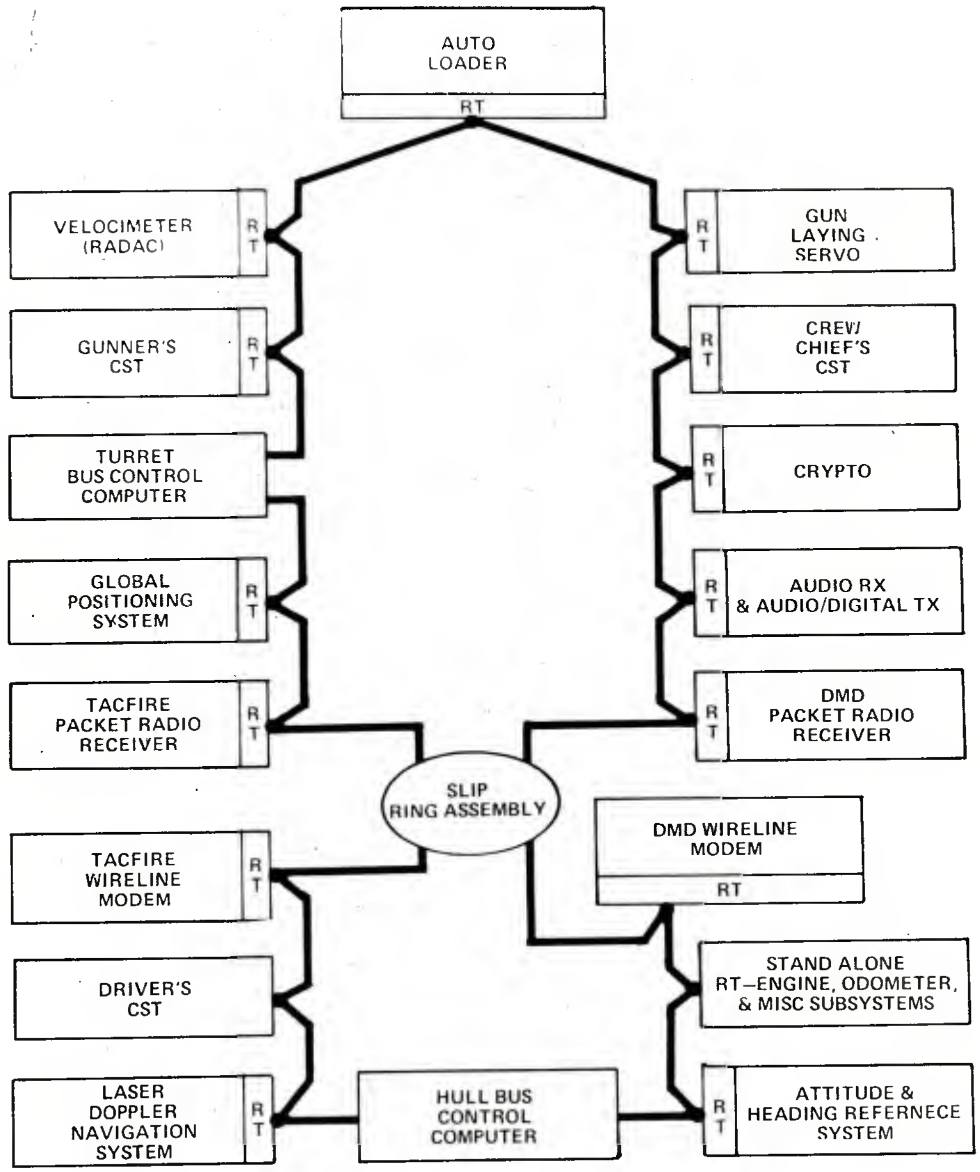



Figure 62 Block Diagram of ATEPS Electronics for a Turreted Chassis

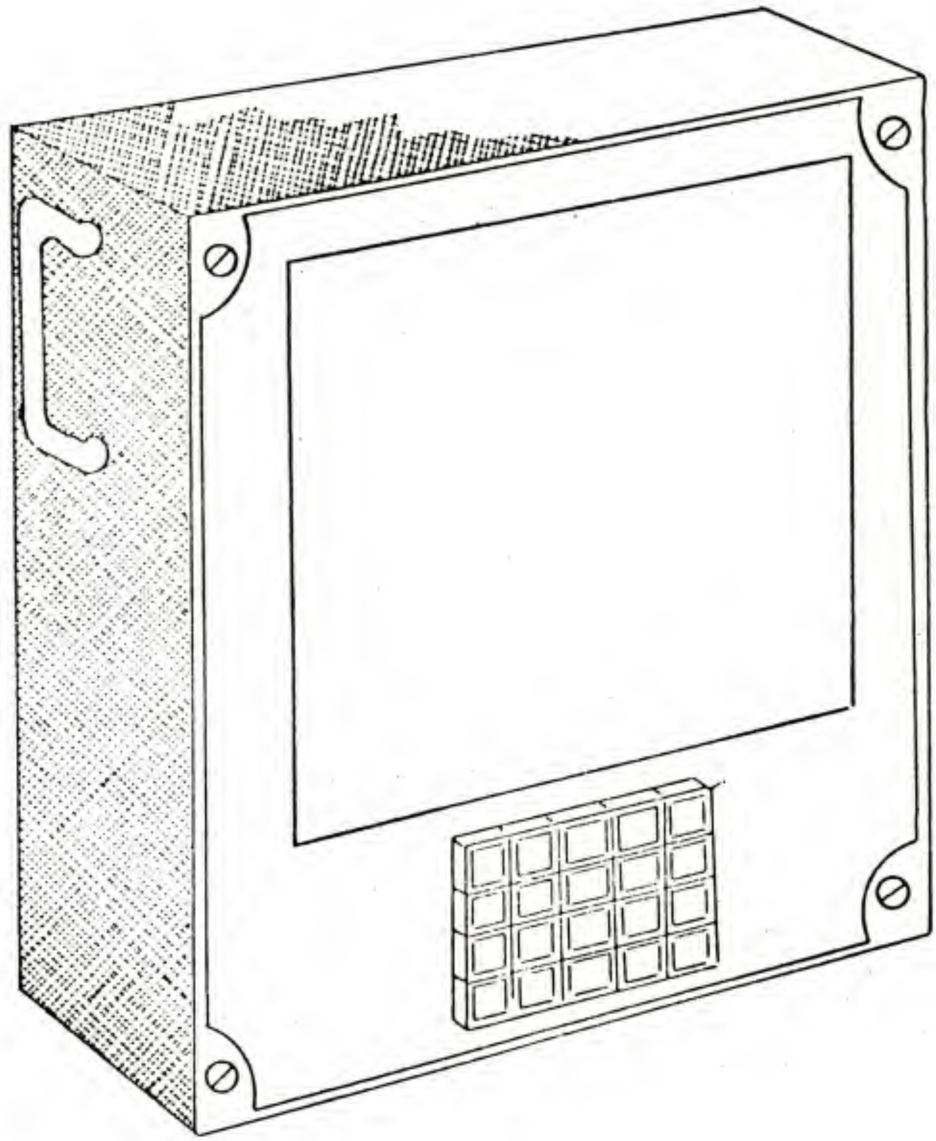


Figure 63 Crew Station Terminal

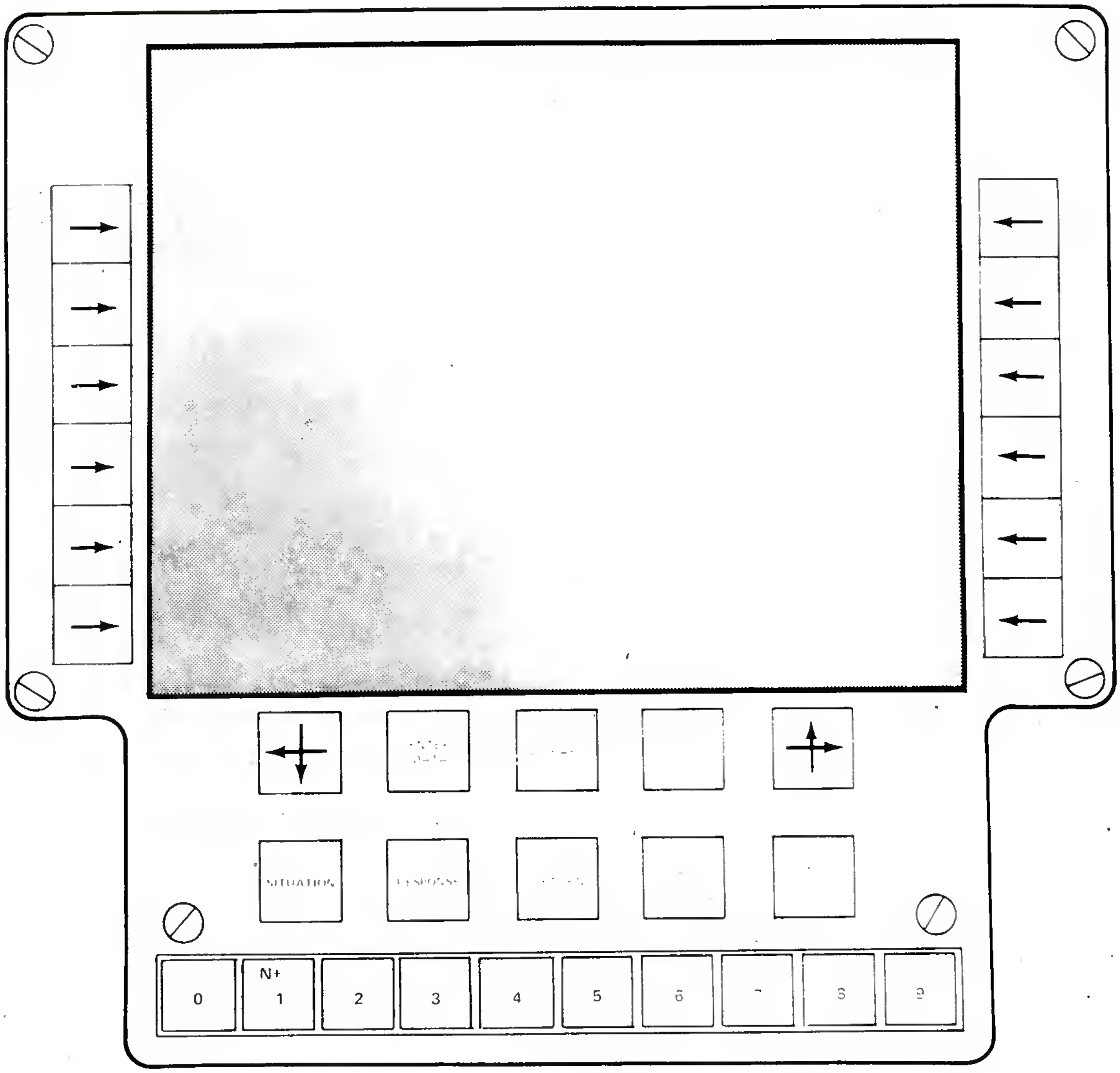



Figure 64 Crew Station Terminal (Optional Design)

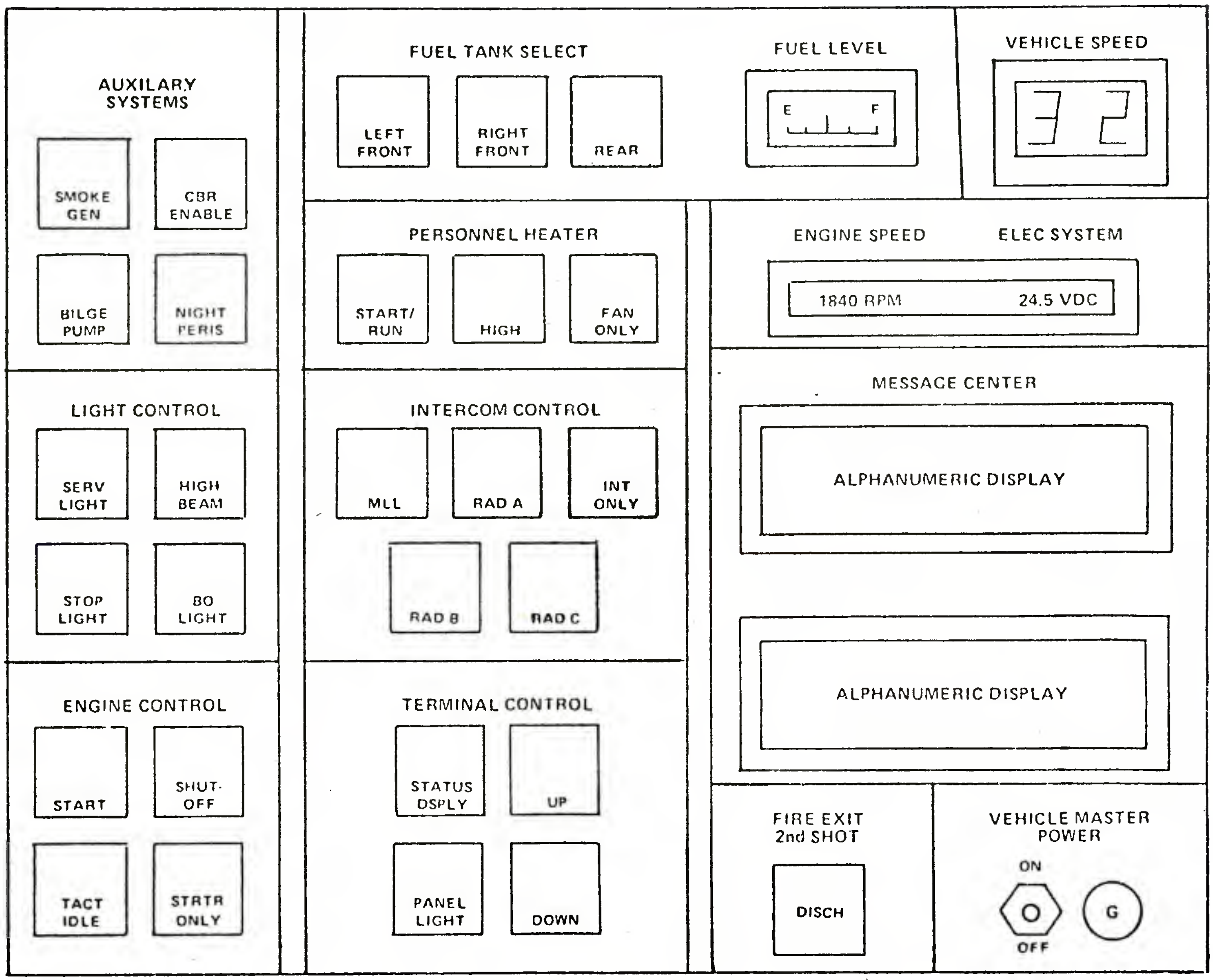



Figure 65 Driver's Terminal

Performs maintenance diagnostics

Provides crew check lists

Controls flow of communications messages

Performs fire control data integration

Commonality

Common ATEPS data bus interface cards

Common microcomputer/memory cards

Identical crew station terminals

In this case, the multiplexing concept study integrated the on-board technical fire control and contained the following key features:

Self-contained gun pointing servo (digital input)

Self-contained radar fuzing subsystem

Gun laying computations by bus control computer

From target coordinates supplied by FO via DMD

From digital data received from TACFIRE

From target coordinates input by SPH crew via ATEPS crew station terminal

Using navigation data

Navigation data mixing by bus control computer (10 meter accuracy)

Global positioning system (GPS) data

Attitude heading and reference systems (AHARS) data

Odometer data

Laser doppler navigation (LADON) data

A computer analysis was made of the time-sharing capability of the bus cables to transmit data and it appears that the data requirements are considerably below the performance capability of the cables.

In order to incorporate multiplexing technology, the following must be defined:

Number and approximate location of bus controllers

System architecture

Bus controller architecture - degree of redundancy, etc.

Delineate subsystems which have imbedded remote terminals (RTS)

In addition, a multiplexing interface control document must be generated to:

a. Designate the use of bus interface standard (MIL-STD-1553B).

b. Specify each type of input/output (I/O) module to be employed in remote terminals.

c. Specify the number of each signal type to be accommodated by each I/O module.

d. Specify output voltages and load capability of each type of signal output.

e. Specify input voltage and impedance range accommodated by each type of signal input.

f. Describe circuits to be employed in imbedded RTS.

g. Specify electromagnetic pulse (EMP) and radiation hardening requirements.

h. Specify overvoltage protection required on each input and output, if any.

In summary, the use of multiplexing in an SPH would appear to:

a. Reduce the complexity, bulk, and problems associated with conventional wiring systems having multiple harnesses.

b. Establish a potential to integrate fire control systems and provide on board diagnostics and prognostics for the electrical, hydraulic, and mechanical systems.

## Alternate Ammunition Handling Concepts (Ammo Focus)

### Background

During the study, ammunition handling became an area of prime activity. It had a major impact on the configuration of the ARV's as well as the SPH's. Several ideas were discussed which were not incorporated in any of the design concepts. It should not be inferred that these ideas were unsound. On the contrary, while many of them were attractive, they simply were not compatible with the overall ammunition handling concept chosen for the particular weapon design. The following paragraphs summarize the more promising ideas for possible use, if additional battery concepts are developed.

### Alternate Pallet Designs

All pallet designs, including those shown with the various concepts, should comply with the following objectives:

Projectile pallets:

a. Loaded weight limitation of 1,500 pounds.

b. Minimum of 10 projectiles per pallet.

c. Fork lift capability.

d. Hook attachments points.

e. Interlock for easy stacking.

f. Projectiles readily fusable in pallet.

g. Protection for rotating and obturator bands.

h. Positive release and retention of projectile.

i. Integration of pallet with SPH ready rack (alignment of projectile center lines with ready rack).

j. Structural integrity during projectile removal.

k. Retention device must be compatible with lifting plug and fuzes.

l. Pallet should be adjustable for minor variations in projectile length.

Propellant pallets:

a. Moisture seal provision.

b. Fork lift capability.

c. Hook attachment points.

d. Interlocked for easy stacking.

e. Positive release and retention of propellant.

f. Integration of pallet with system.

g. Structural integrity during propellant removal.

The following projectile and propellant pallet configurations were considered:

a. An all steel pallet (figure 66) to handle projectiles of various lengths. The projectile is inserted from the brace end until the rotating band contacts the metal sleeve. The retention brace is then inserted and locked behind the projectile base.

b. An all steel projectile pallet (figure 67) which utilizes a quick-release push-pull bar mechanism in contact with the ogive to provide retention. Ratchet pawls provide base retention for various length projectiles. Part 2 of the figure shows two pallets stacked in an interlocked configuration.

c. A nonmetallic projectile pallet (figure 68) consisting of fore and aft sections secured with steel bands and employing metallic T-shaped sections for rigidity. The rear of the pallet is recessed to accept and protect the rotating band. The front of the pallet matches the projectile's ogive angle. Three separate banding operations permit pallet disassembly in layers while retaining structural integrity.

d. The projectile pallet in figure 69 consists of multiple interlocked layers to maximize pallet flexibility. The layers are interlocked with quick-release pins. The projectiles are secured in slotted nonmetallic tubes via a cable bellcrank system which exerts radial forces on the bourllet and/or rotating band.

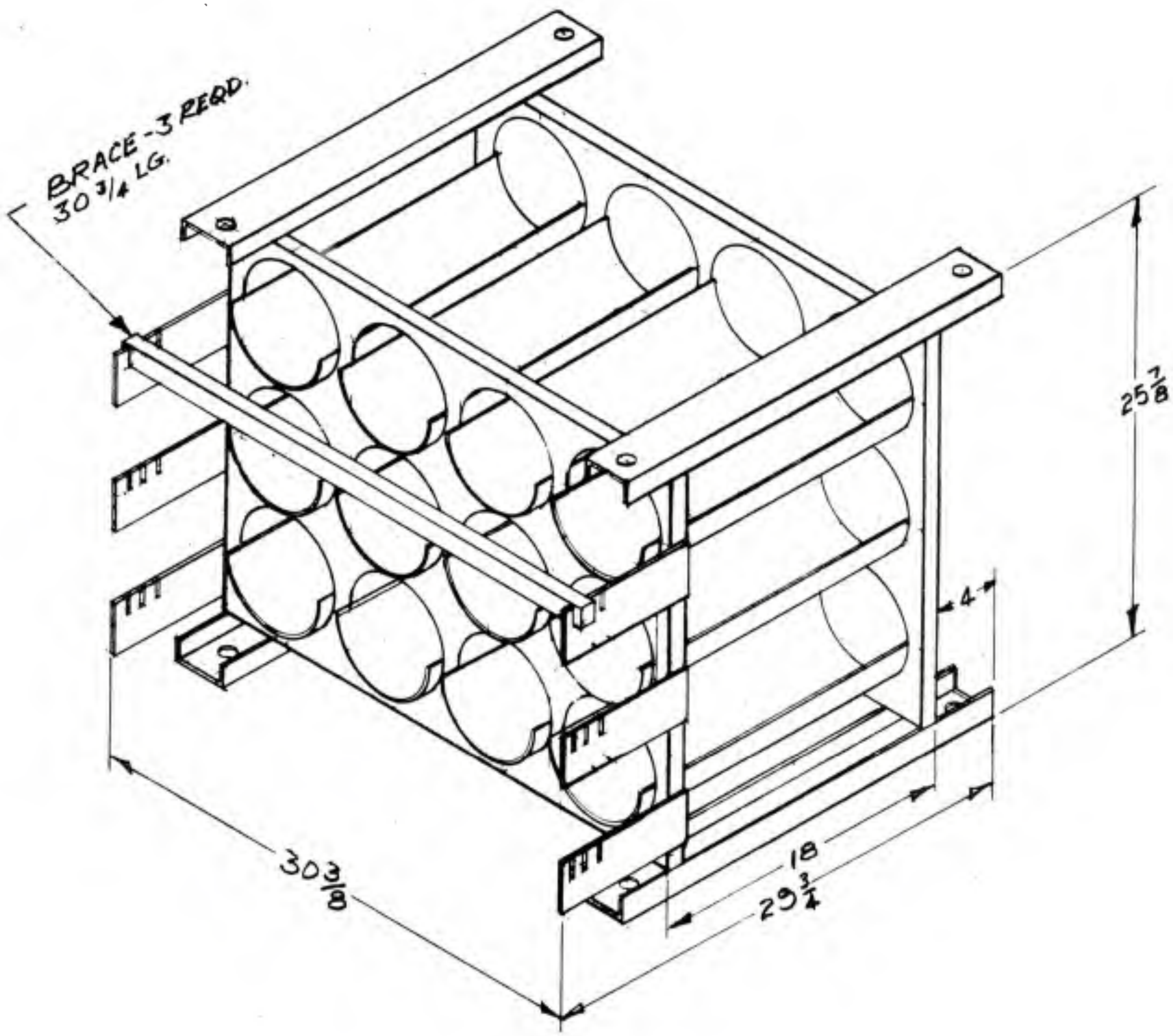



Figure 66    155mm Projectile Pallet (Design 1)

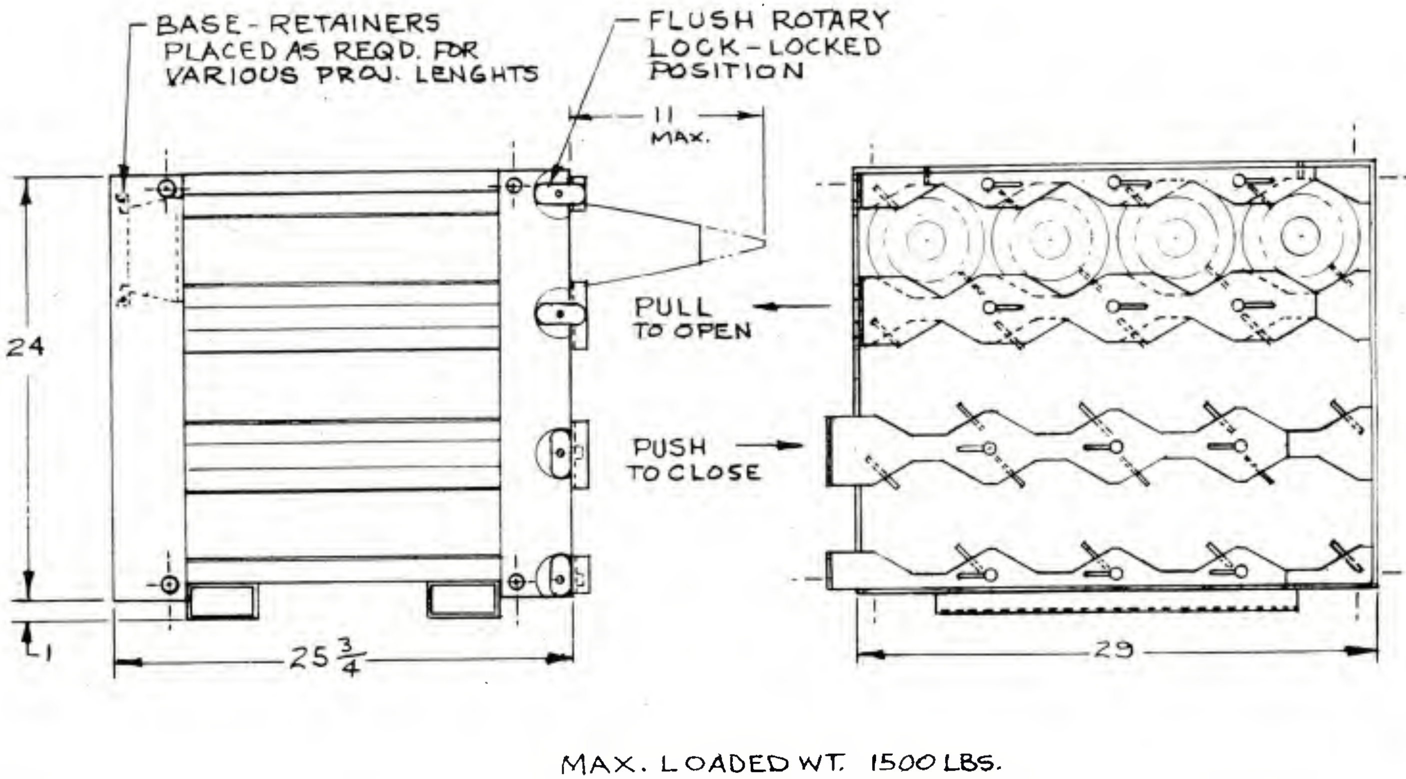



Figure 67 155mm Projectile Pallet (Design 2-Part 1 of 2)

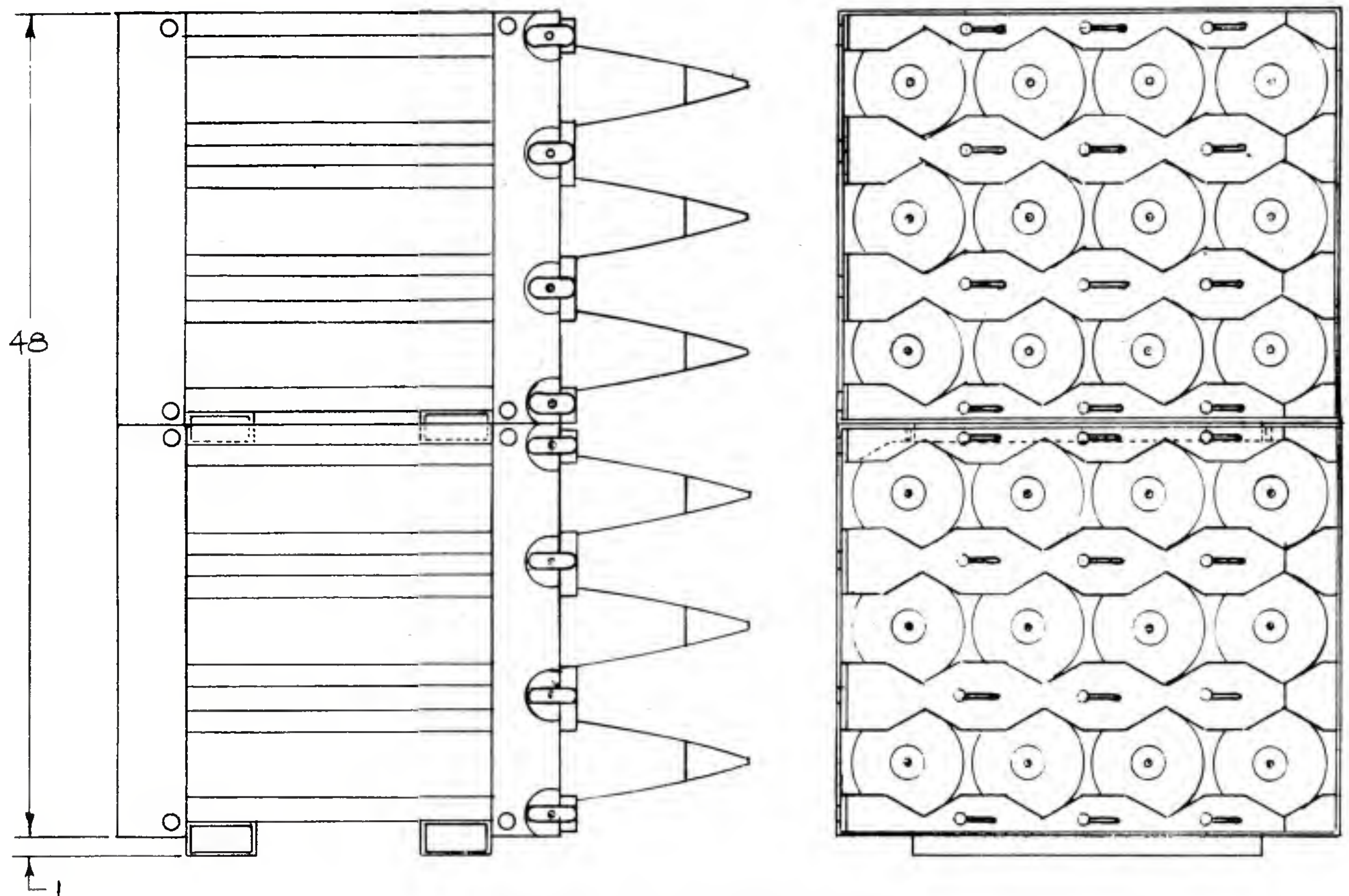



Figure 67 155mm Projectile Pallet (Design 2-Part 2 of 2)

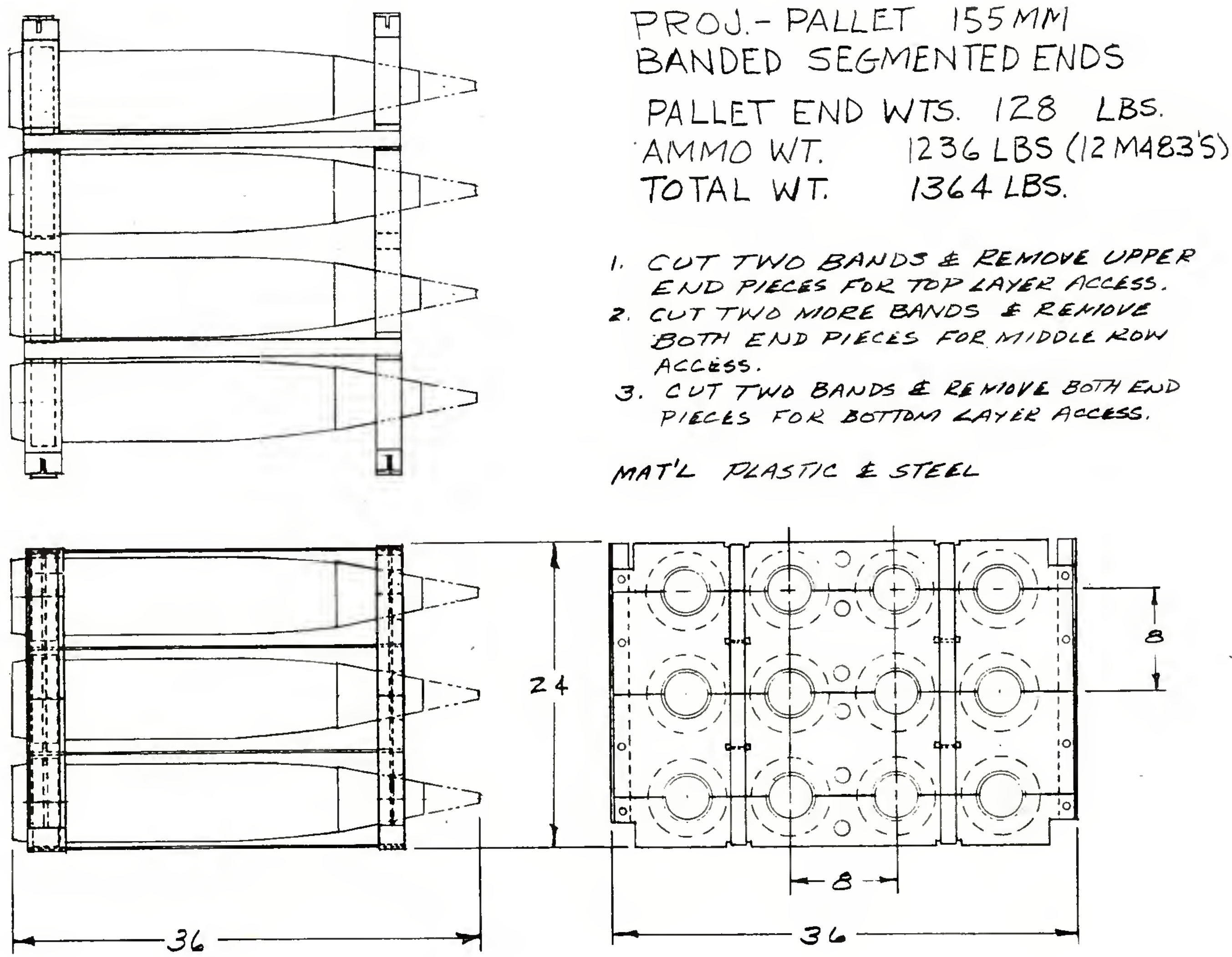



Figure 68 155mm Projectile Pallet (Design 3)

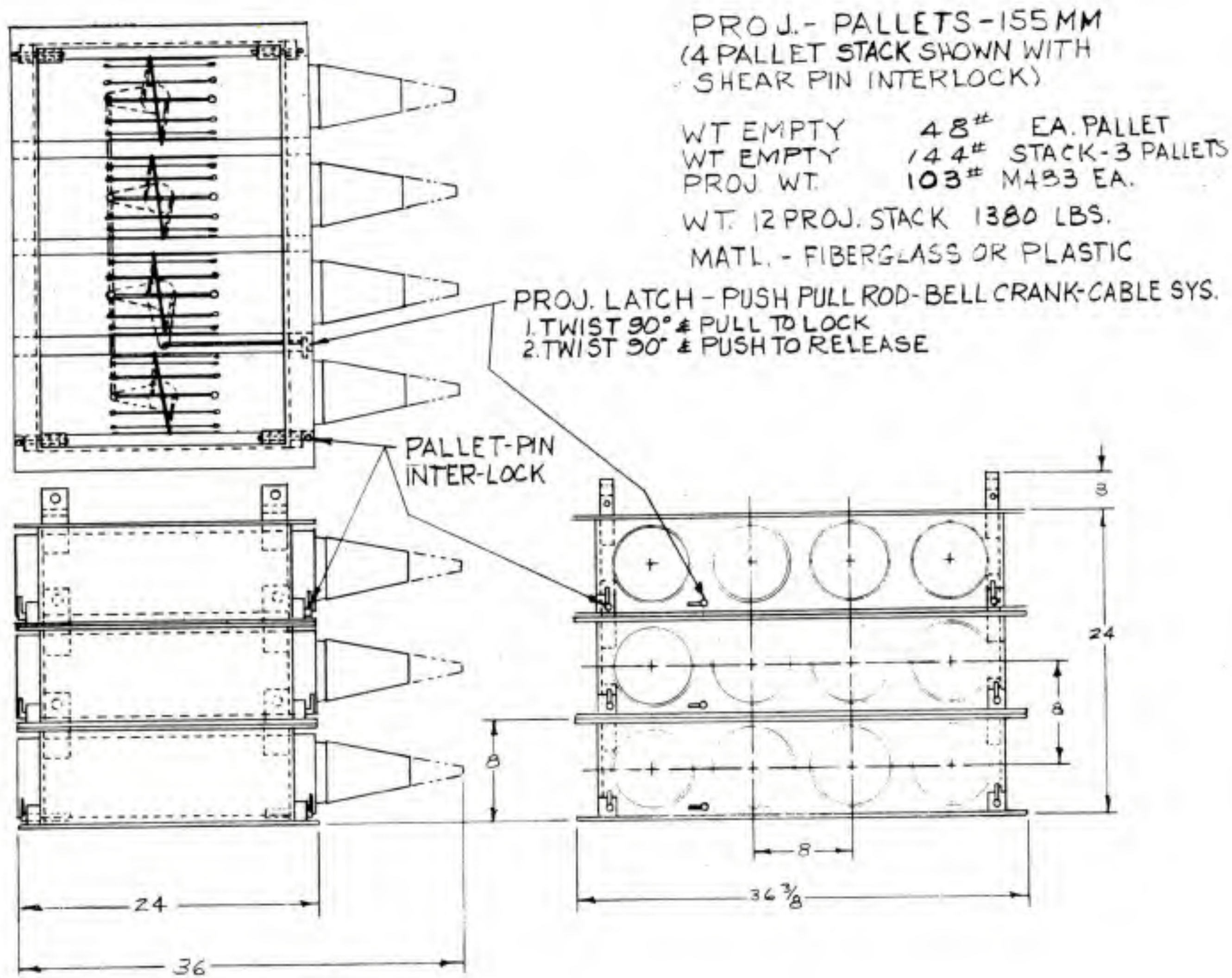



Figure 69 155mm Projectile Pallet (Design 4)

e. The propellant pallet in figure 70 is similar to the projectile pallet in figure 67 except that full length steel tubes with end seals and quick-release caps are utilized. Various lengths can be accommodated by utilizing a quick-release positioner.

f. Construction of the propellant pallet in figure 71 is similar to the projectile pallet in figure 69 except the tubes are heremetically sealed by individual end caps. The propellant may be removed from either end.

Wheeled Ammunition Resupply Vehicle (ARV)

Early in the study a decision was made to use ARV's in some form to ease the ammunition handling problems. In addition, because of limited data, it was decided that all ARV's would be tracked. As more information became available from the heavy expanded mobility tactical truck (HEMTT) program, a question was raised concerning the use of a wheeled ARV. While it is recognized that wheeled ARV's are not as mobile as a tracked SPH, they probably have 80-to 90-percent of its mobility. Conceptually, this slight reduction in mobility would probably be offset for those concepts which use the shoot and scoot mode of operation. For such concepts the ARV would be with the SPH only as required. The wheeled ARV could carry 120 rounds, and would use its on-board crane to unload projectile and propellant pallets onto a tailgate such as is shown in some of the Class II and III SPH concepts. (Preliminary concept efforts were initiated for unarmored wheeled ARV. As the concepts evolved, it became evident the conceptual ammunition resupply trucks would need very little modification to meet ARV requirements.)

The following summarizes the key characteristics of wheeled ARV's:

1. Use of either an articulated or straight bed truck appears to be a reasonably acceptable approach.

2. While wheeled truck beds seem to be limited to an 8-foot width, which is narrower than tracked vehicles, this does not appear to limit the payload since longer truck beds could be used.

3. A wheeled ARV seems to be compatible with a shoot and scoot battery concept since it does not necessarily have to move into the firing area where its unarmored configuration would tend to make it vulnerable to counterbattery fire.

4. An unarmored wheeled ARV can carry about the same number of rounds as an unarmored tracked ARV.

5. An unarmored wheeled ARV's load carrying capacity is limited by

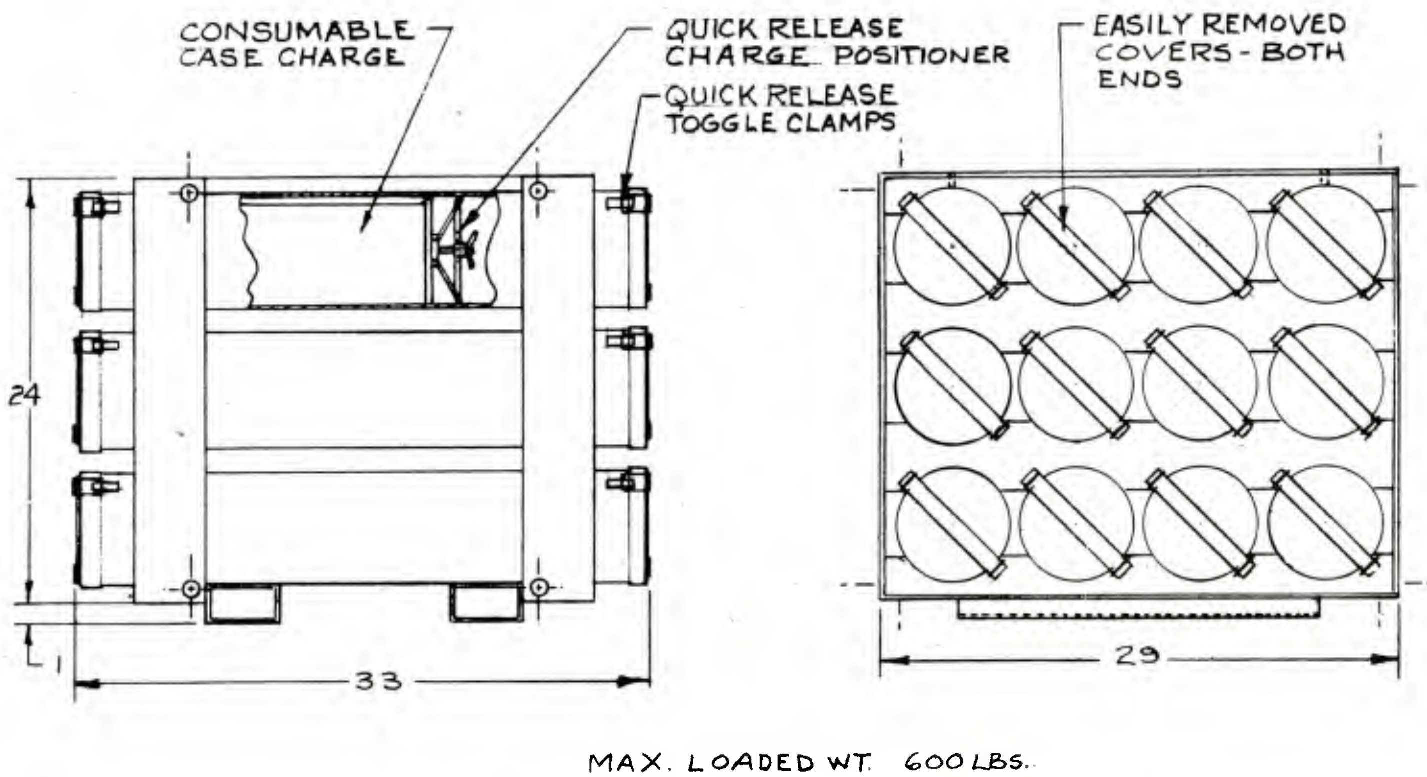



Figure 70 155mm Propellant Pallet (Design 1)

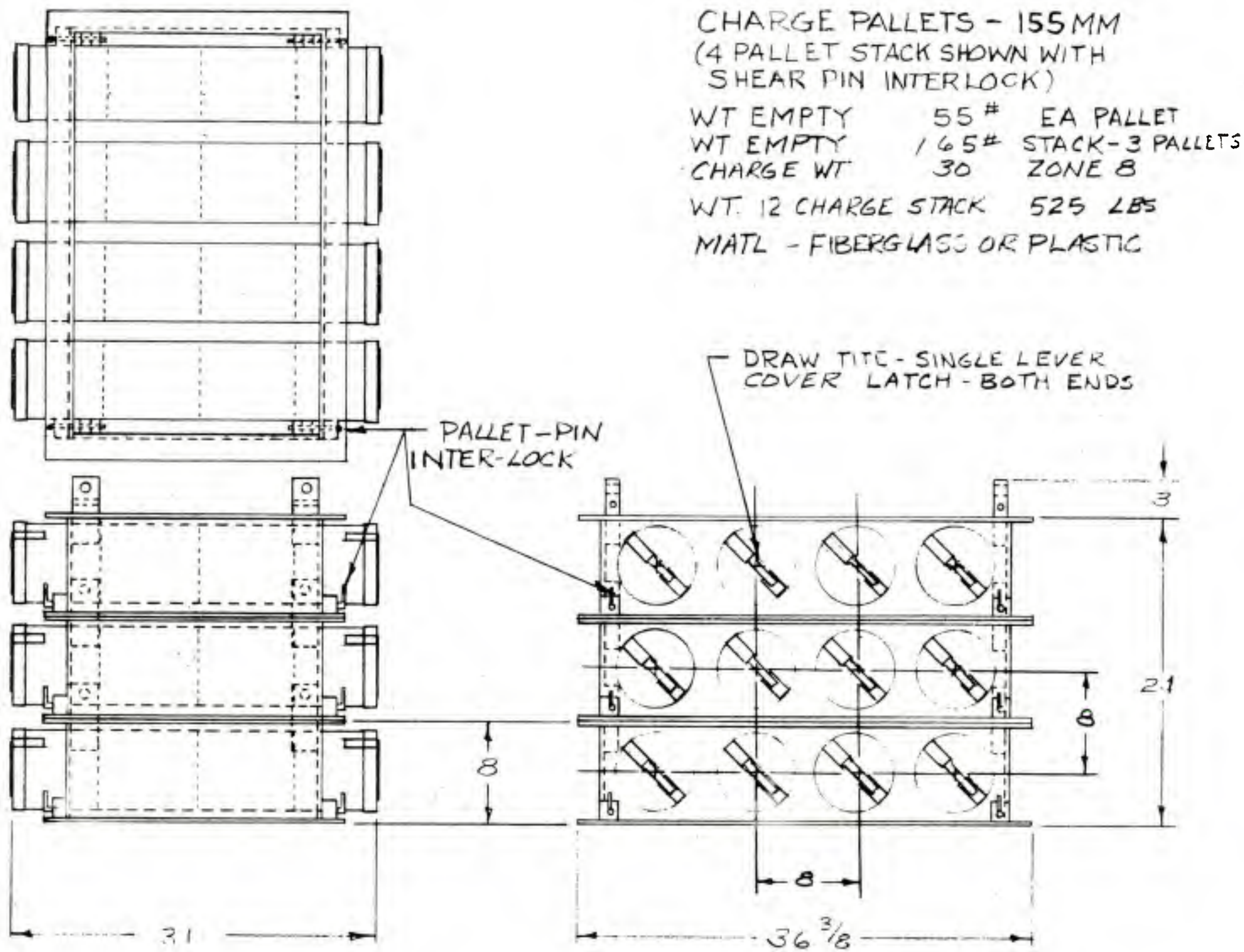



Figure 71 155mm Propellant Pallet (Design 2) side slip stability rather than overall weight or space considerations.

6. Future battery weapon concepts should consider a wheeled ARV and the battery ammunition resupply truck as a single vehicle and thus potentially eliminate the requirement for a special ARV. While not fully evaluated in this study, more ammunition handling equipment may be required on the SPH in order to ease ammunition transfer problems.

Casemate Self-Propelled Howitzer with Selective Propellant Charge Loader

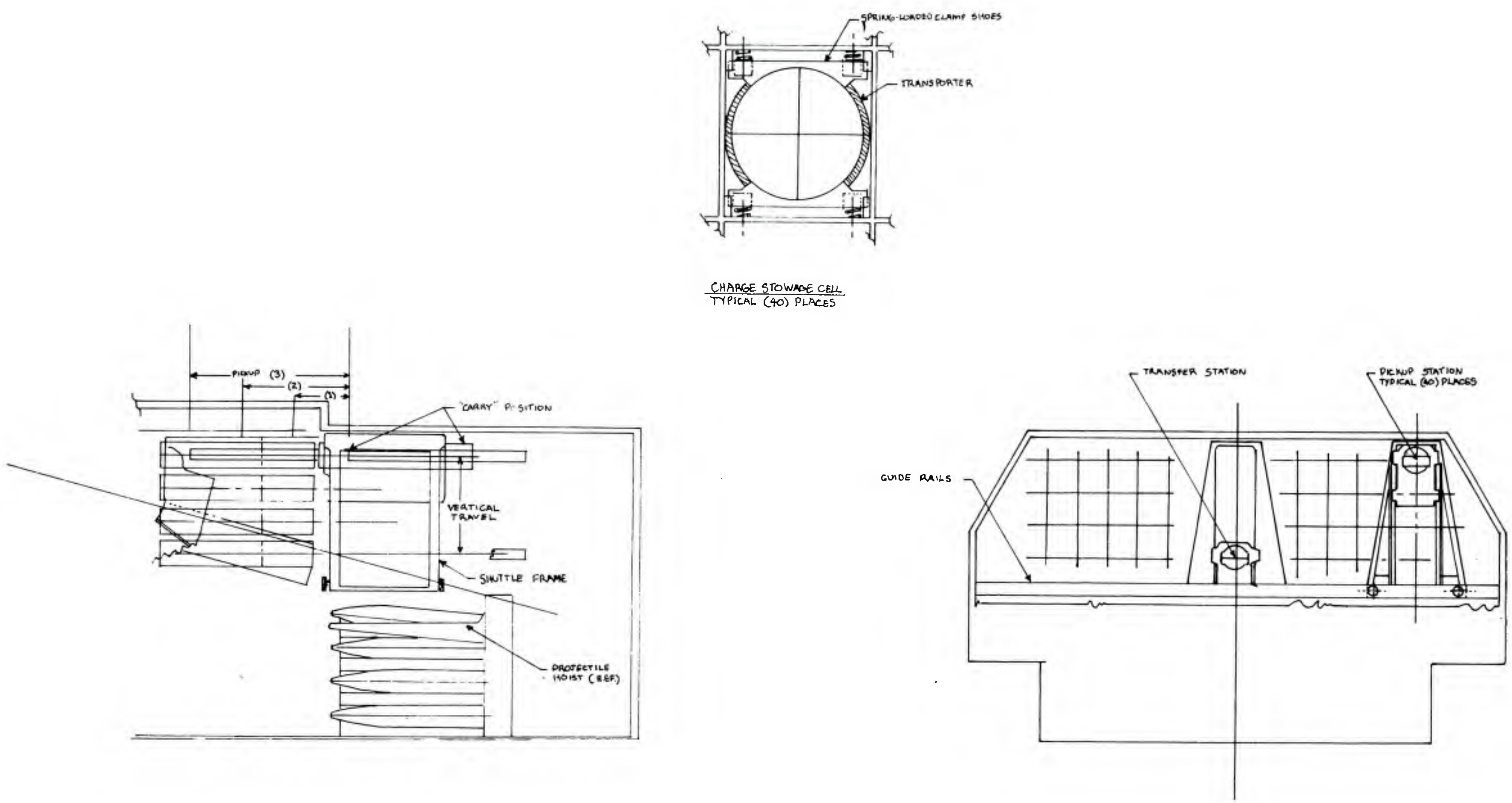
This concept uses a projectile loader and ready rack mechanism similar to Concept IVB. However, a different mechanism is used for loading propellant charges. See figure 72. Modular charges are stored in honeycomb racks across the cab above and forward of the projectile loader. The central area is clear to provide recoil space for the breech.

The loader is a shuttle and, in effect, is a 3-degree-of-freedom gantry. It contains carrier jaws which extend a programmed distance into a charge stowage cell to engage the required number of charges, cam open the stationary holding jaws, and withdraw the desired charge. These jaws are carried up or down along a pair of vertical guides in the shuttle frame which, in turn, can travel across the cab on horizontal tracks. In this manner the hoist is programmed to align with the nearest full storage cell, withdraw the required number of increments, move them to the transfer point, and transfer them to the flick rammer tray after the projectile has been rammed. When the carrier jaws are retracted to their "carry" position, the entire mechanism is clear of other moving or recoiling parts and can operate independently of loading, aiming, and firing operations. Propellant transfer takes place at the same QE (15 degrees) as projectile transfer and ramming.

Ammunition Truck with X-Y Trolly

In general, all weapon concepts were developed using unmodified ammunition resupply trucks. However, some thought was given to advantages which might be gained by adding special ammunition handling equipment to the trucks.

Figure 73 shows an ammunition resupply truck with X-Y trolly mounted on its bed. The shuttle would be capable of moving in two dimensions above the projectile and propellant pallets to pick them up and to transfer them to the rear of the truck where they would be off-loaded onto another vehicle. As shown in the figure, projectiles are being off-loaded into an ARV; however, depending upon the particular battery weapon concept developed, the projectiles could be off-loaded into the rear of an SPH. In addition, the X-Y trolly could be used at the ATP or ASP to pick up projectile and propellant pallets. The X-Y trolly is shown mounted on the current 5-ton truck, but initial evaluations indicate that it could also be installed on developmental trucks.




CASEMATE
AMMUNITION FOCUS
(40) PROP CHARGE CAP.
SELECTIVE LOADER
WS-000076

Figure 72 Casemate Self-Propelled Howitzer with Selective Propellant Charge Loader (Ammo Focus)

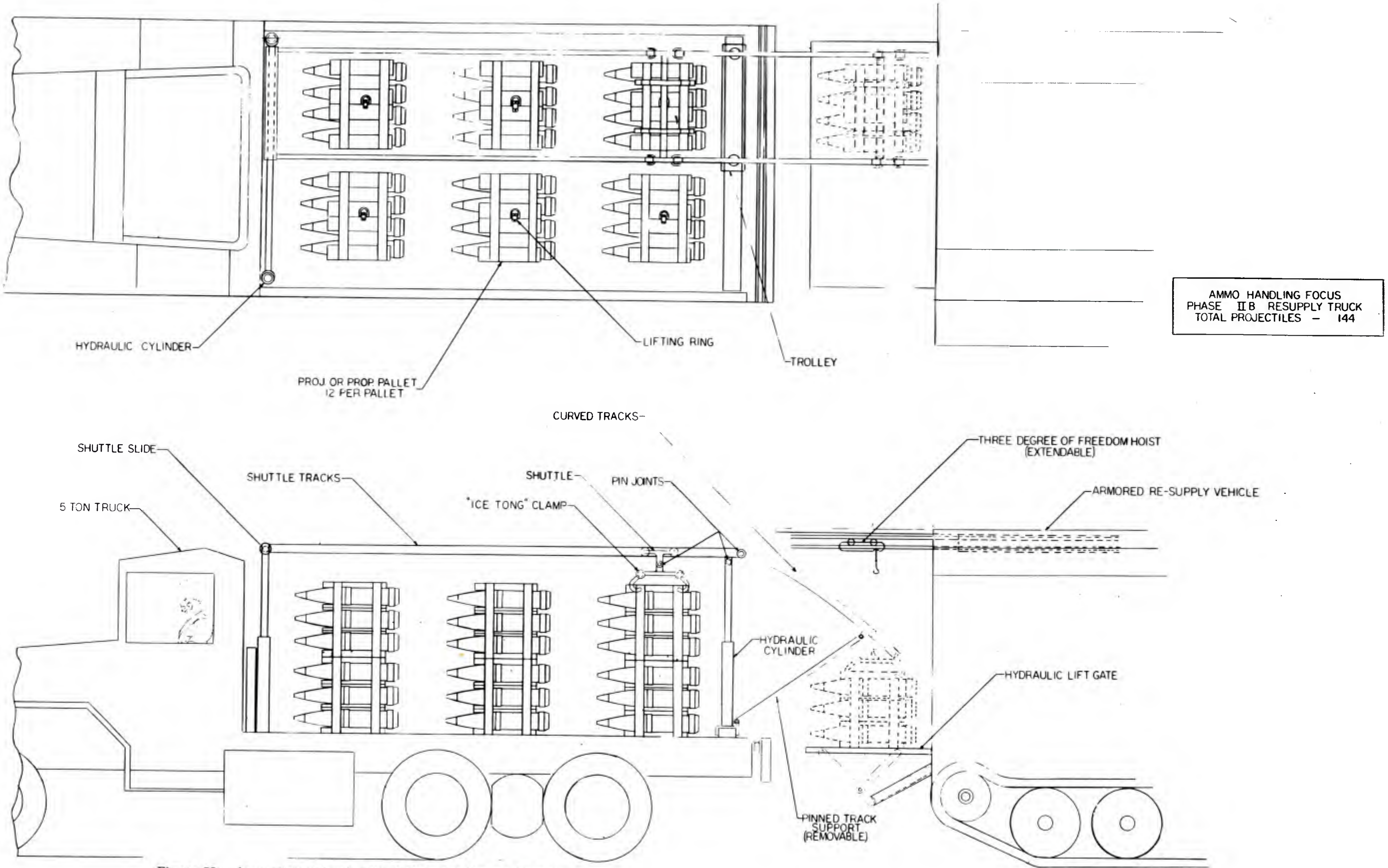



**Figure 73** Ammunition Truck with X-Y Trolly (Ammo Focus)

Casemate Self-Propelled Howitzer with 4-Projectile Clip

The objective in developing the casemate SPH shown in figure 74 was to evaluate loader rammers which could use a 4-projectile clip. The concept as shown would transfer projectiles into the SPH by an overhead trolly where they would subsequently be installed in a projectile ready rack to the right of the cannon. Similarly, propellant charges in a 4-clip configuration would be transferred into a gravity-fed charge hopper. As shown, each charge cannister would contain four incremental units to provide the necessary zoning solution as described in the Class II concepts.

Once the projectile clips are loaded into the ready rack, the loader can function. Each clip is held by two prongs which are cantilevered from the clip retainer. After the pallet bands are automatically removed, the clips are lowered as required. The ready rack mechanism selects a projectile from the bottom of any of the four columns and lowers it onto a conveyor which moves it to the centrally located loader-rammer. At the same time, the gravity-fed hopper selects the required number of incremental charges and transfers them to the loader-rammer. After the projectile and charge are placed on the loader-rammer, it automatically elevates to the firing position where the projectile and charge are sequentially rammed into the cannon.

Casemate Armored Resupply Vehicle with 4-Projectile Clip

Figure 75 illustrates an ARV designed to transport 4-projectile clips. A total of 96 projectiles and 96 charges are carried. Each projectile pallet is comprised of three clips vertically oriented as shown in the figure. The propellant is packaged in a sealed cannister in four full charges (16 segments). The MLRS chassis is used in an armored configuration. The projectile pallets are evenly divided, four pallets over each sponson; and the charges are stored two deep across the front of the cargo area. To move the payload into and out of the ARV, an extendable X-Y hoist is used. Once the cargo is introduced into the ARV from the resupply truck, the ammunition handler can either manually push the pallets down the roller conveyor to the storage position or use the X-Y hoist to stow the pallet.

Casemate Self-Propelled Howitzer with Floor-Mounted Ammunition Handling System

Figure 76 illustrates an SPH with a floor-mounted ammunition handling system. Thirty-eight complete rounds are stored vertically near the floor of the vehicle with projectiles on one side of the breech block and propellant charges on the other side. The projectiles and charges are constrained from lateral motion and tipping by pairs of track-guided, hydraulically-operated pawls and quick-clamping release mechanisms (figure 77). Ammunition selectivity is provided by six exits at the front of the ready racks (three for the projectiles and three for the charges). The remaining eight projectiles and charges, located at the extreme left and right positions, may be passed forward only when their adjacent rows are empty. These eight complete rounds may be considered as backup rounds.

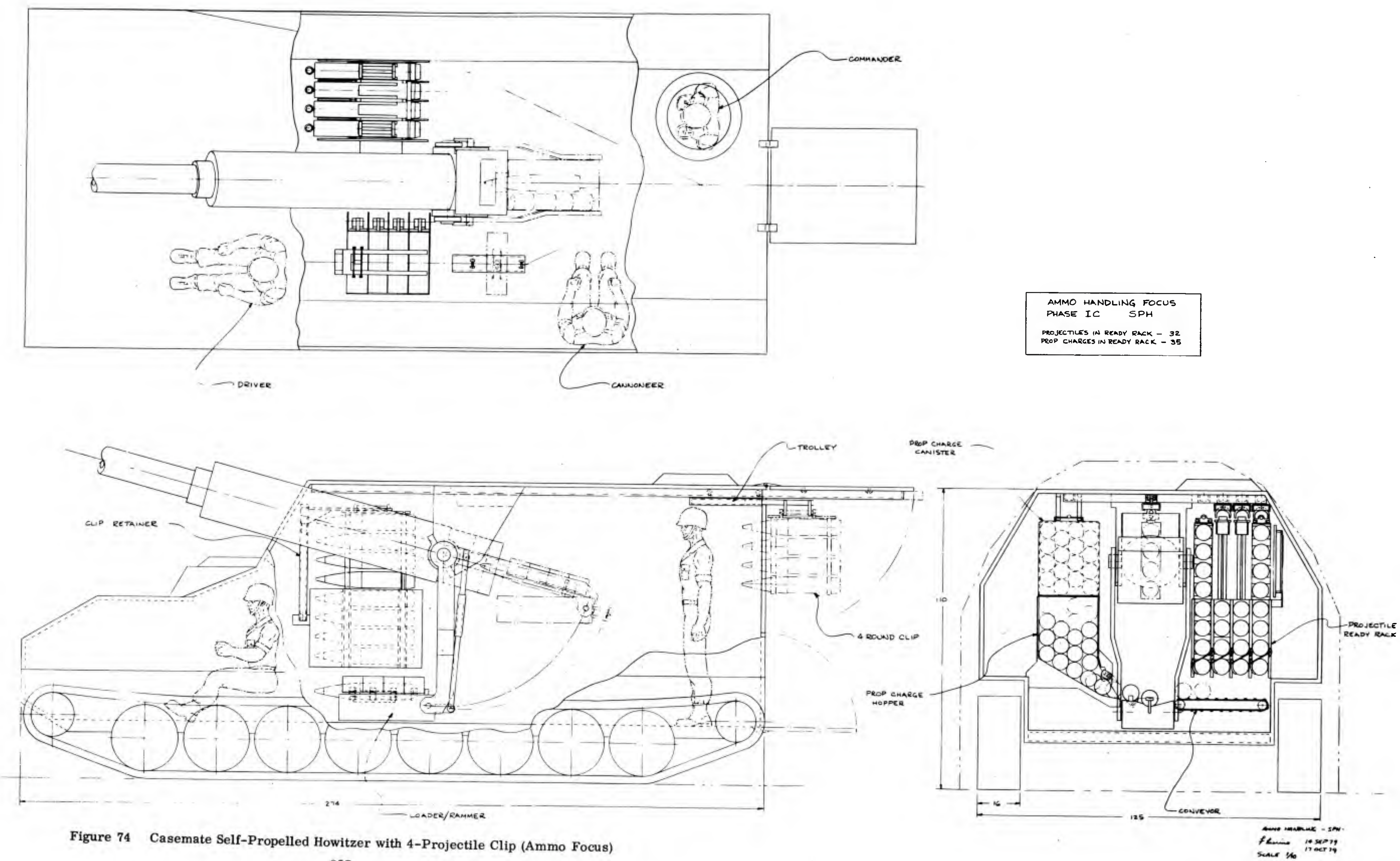



Figure 74 Casemate Self-Propelled Howitzer with 4-Projectile Clip (Ammo Focus)

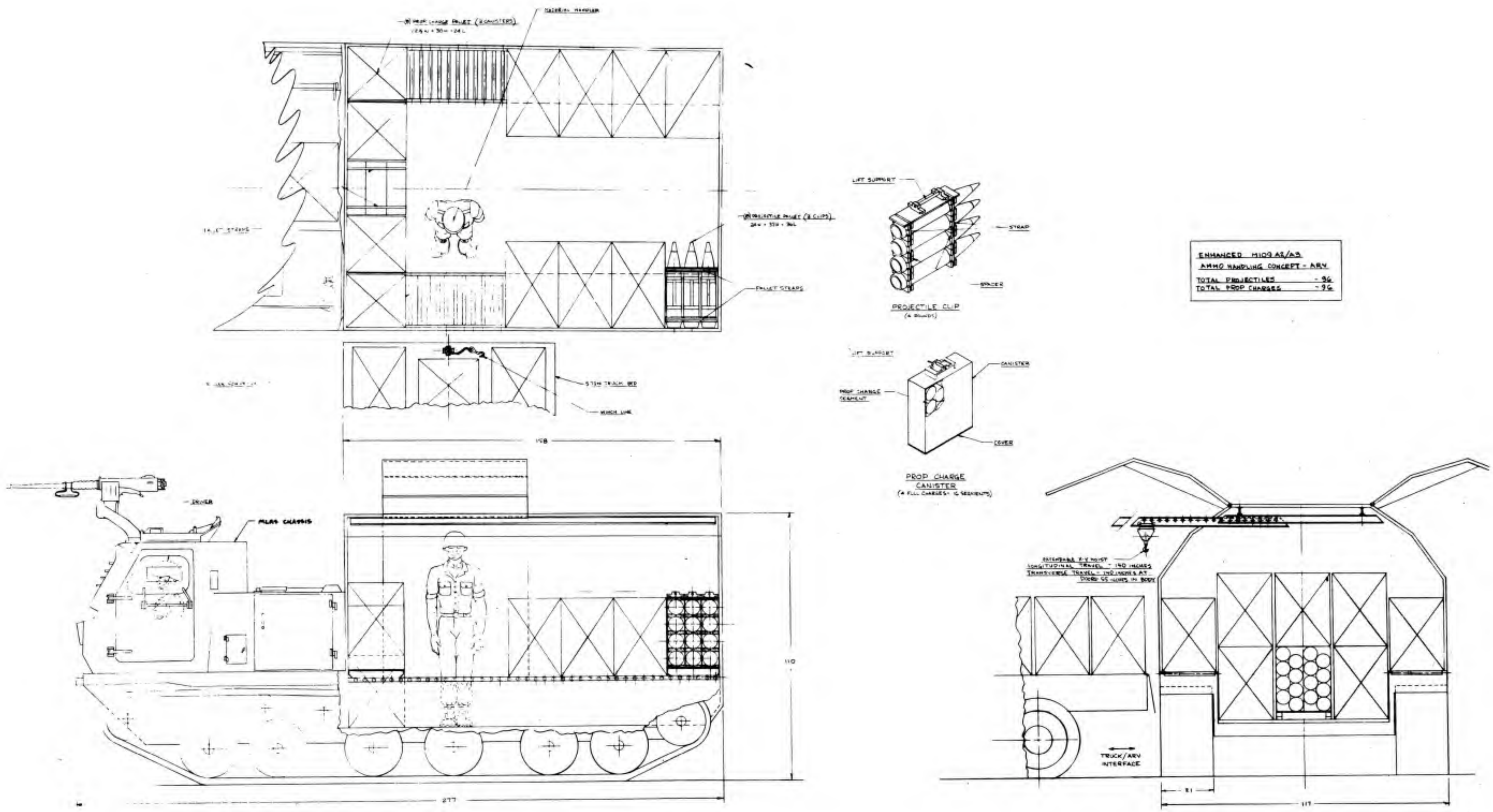



Figure 75 Casemate Armored Resupply Vehicle with 4-Projectile Clip (Ammo Focus)

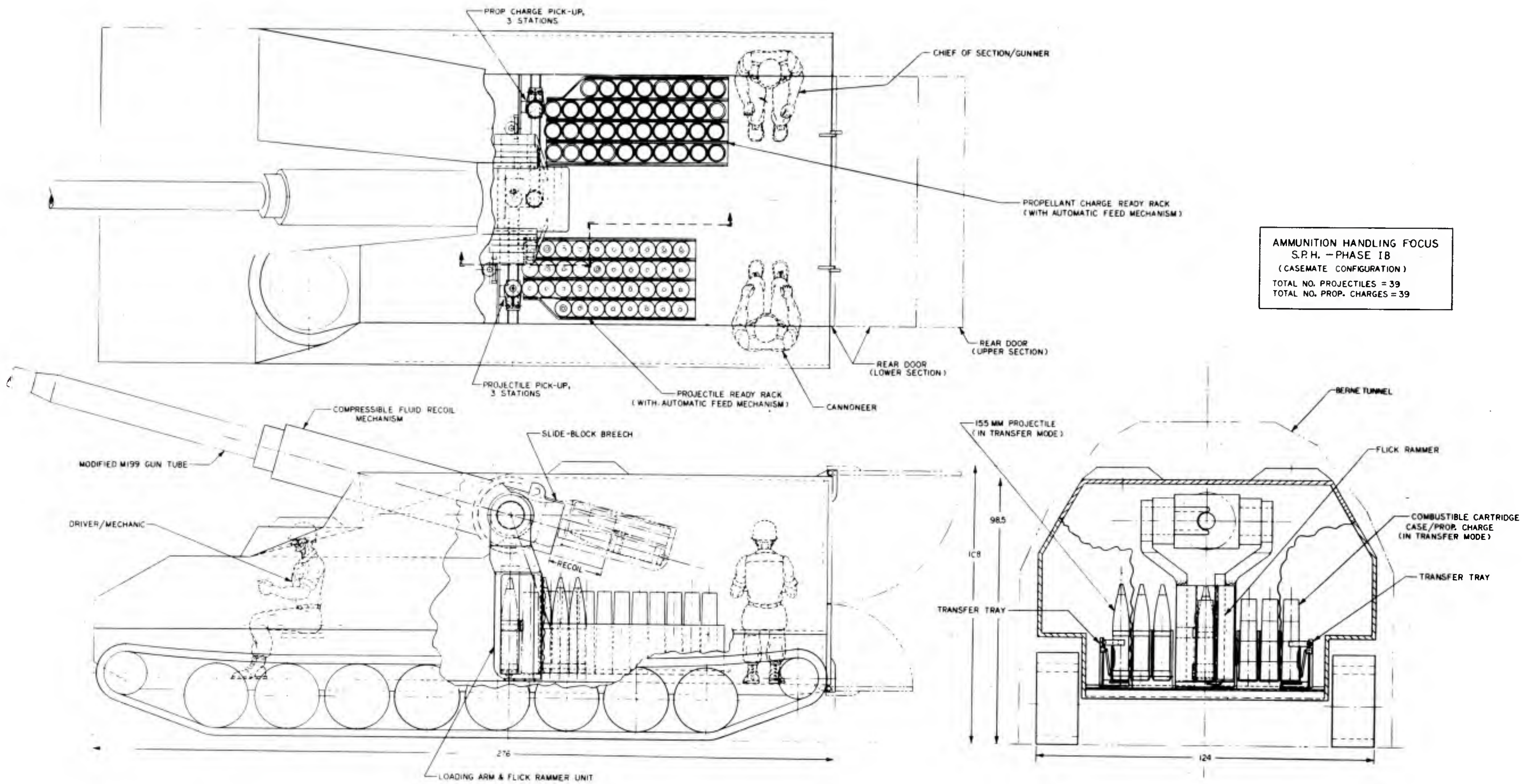



Figure 76 Casemate Self-Propelled Howitzer with Floor-Mounted Ammunition Handling System (Ammo Focus)

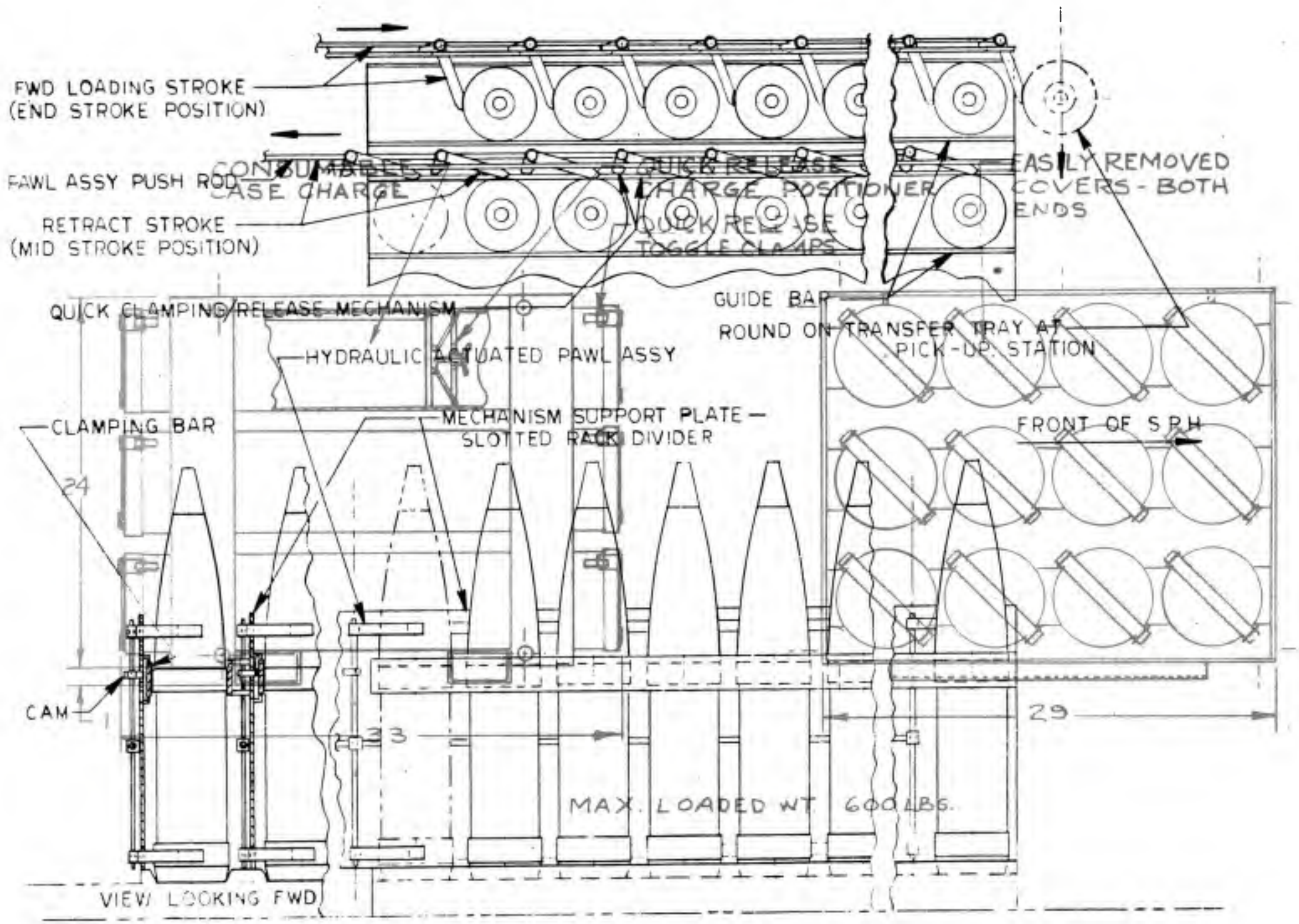



Figure 77 Ready Rack Auto-Feed Mechanism (Ammo Focus)

Ammunition is fed onto the ready racks through the eight entrances near the rear of the SPH. (Sufficient floor space is available behind the ready rack for loading operations.) See figure 78 for a view of the transfer of ammunition from an ARV into the SPH. The pawl assemblies associated with each of the eight auto-feed mechanisms are used to snare a round as it is fed onto the ready rack. By activating the push rods, the round advances one caliber. When the pawl assemblies are cycled to their original positions, the rounds being fed forward are held firmly by the synchronized quick-clamping/release mechanism. Thus, each round is fully supported while the ready rack "clip" is replenished. All projectile and charge "clips" may be simultaneously loaded.

Mounted at the front of the ready racks are a pair of ammunition transfer trays which receive, respectively, the selected projectile and charge before transferring the complete round onto a trunnion-mounted loading arm/rammer assembly. See figure 79 for an operational view. Indexed lateral stops are provided to bring the projectile (or propellant charge) transfer tray in direct alignment with the selected round. A chain drive mechanism is used. By activating the pawl mechanisms of the ready rack, the round is passed forward and released onto the transfer tray. The transfer tray consists of a quick-clamping/release mechanism which holds the round in its upright position while it is being transferred laterally toward the loading arm/rammer,and a slide mechanism pushes the round (or charge) onto the loading arm/rammer housing assembly.

The loading arm/rammer mechanism is used to position a complete round (projectile and charge) in direct alignment with the slide-block breech for ramming into the gun. The flick rammer is an integral part of the loading arm and is placed at the side of the projectile chamber from which the projectile and charge will be sequentially rammed.

The loading cycle begins when the loading arm/ramming mechanism returns to its vertical position directly under the trunnion. In this orientation a "trap door" closes to form the forward (eventually bottom) side of the charge compartment or chamber. The projectile and charge are thus separated when they are simultaneously positioned in the loading arm by the individual transfer trays. Safety arms close immediately on the sides of the projectile and charge chambers as the transfer trays retreat to a programmed pick-up station.

The loading arm/rammer mechanism is then hydraulically rotated upward and automatically locked into ramming position with the projectile chamber aligned with the open breech block, (Under appropriate digital control, this cycle could conceivably occur simultaneously with QE aiming.) A signal energizes the flick rammer and the projectile is rammed forward (the momentum derived from the ramming pawl seats the projectile in the chamber). Immediately, the "trap door" supporting the charge is rotated downward, allowing the charge to slide down into the chamber where it is rammed by a controlled stroke of the flick rammer. The sliding breech block

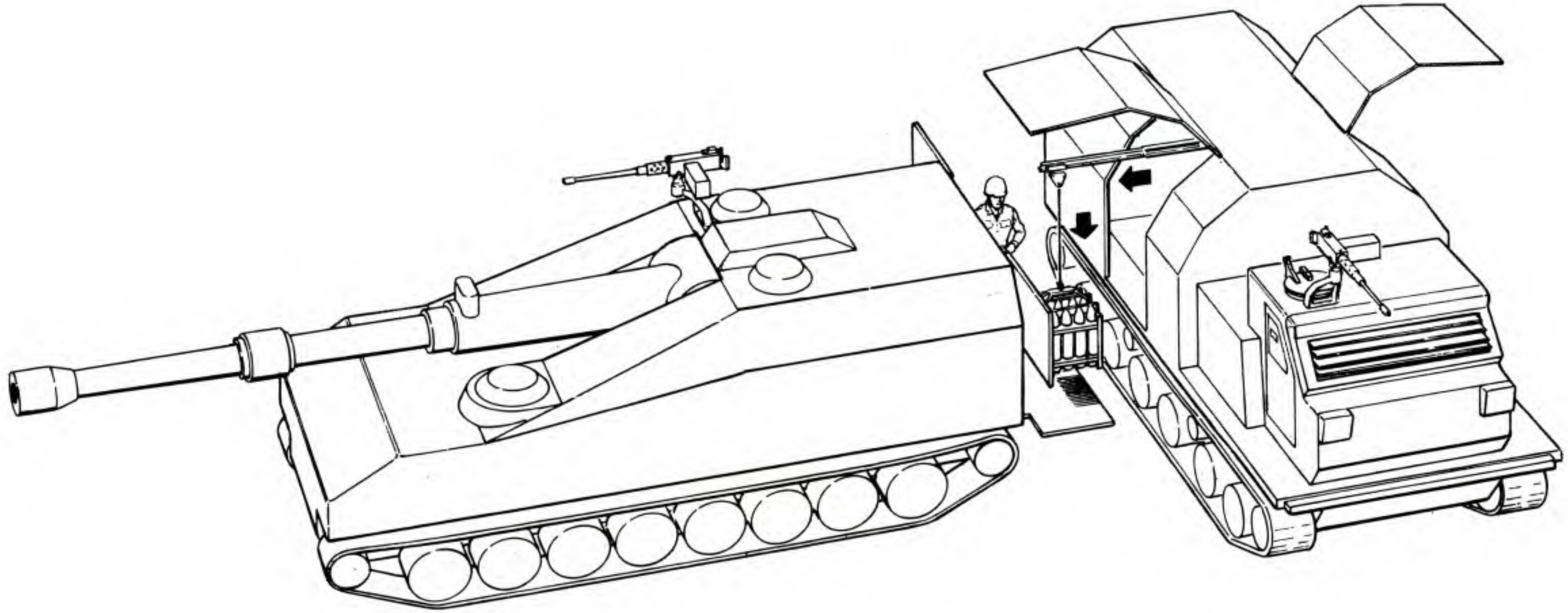


Figure 78    Transfer of Ammunition from ARV to SPH (Ammo Focus)

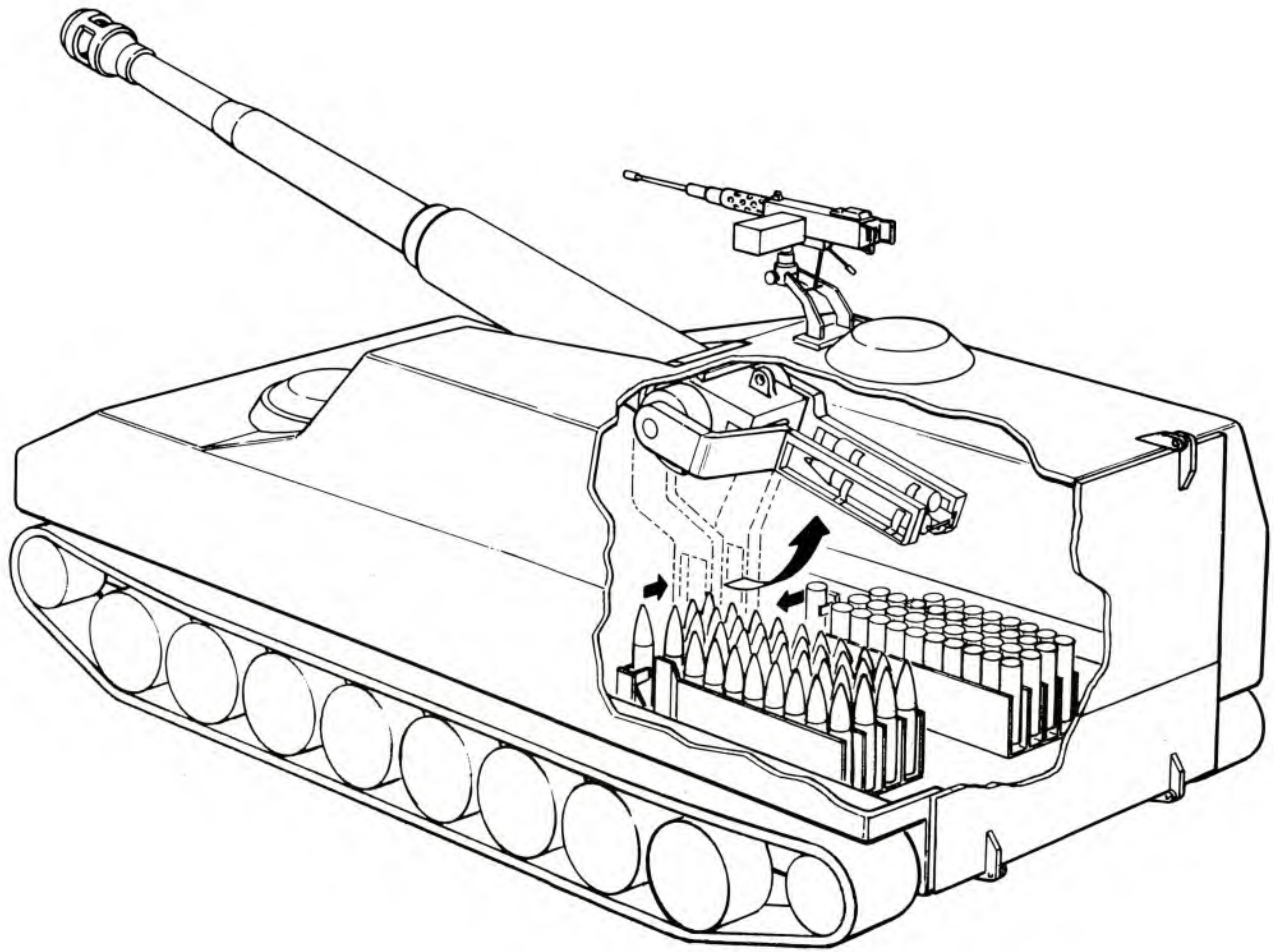


Figure 79 Operational View of Loading Arm/Rammer Assembly (Ammo Focus)

is secured in its firing mode and the loading arm rotates down to receive the next round from the waiting transfer trays as the gun fires.

## Risk Assessment

The ASES concepts were developed in response to firepower requirements and the perceived threat. The approach taken was to exploit current and projected technology in order to develop a battery waepon system of the highest potential. In general, no concepts were generated which were beyond the state of the art projected for the 1982/1983 time frame. The following factors were utilized to determine the level of technology required for development of the concepts.

a. The overall ESPAWS program is oriented toward developing battery weapon concepts in the concept formulation phase leading to ASARC I in FY 82.

b. Following ASARC I, competing contractors will design and fabricate advance development prototypes for the full system concept and be ready for a competitive shotoff within 30 months. (Therefore, technology exploitation was limited to those areas where it could be advanced to a state such that in FY 82 a contractor could realistically start the design of a complete advanced development prototype battery weapon system).

c. No high-risk approaches were used.

In view of the preceding guidelines it is believed each of the concepts is within the state of the art projected for the 1982/1983 time frame.

Following is a summary of the pacing problems which may require hardware experimental test evaluations:

Chassis Components

Weapon azimuth drive working through the transmission

Use of an APU in lieu of batteries or accumulator to provide power while firing

A 600-hp engine/transmission

Fire Control/Weapon Controls

Land navigation/automatic north pointing combined with automatic weapon laying

SPH on-board technical fire control

Improved battery weapon/voice and data transmission capability

Ammunition Handling

Mechanized SPH loading and ramming

Improved ammunition transfer among trucks/ARV/SPH

Improved pallets and containers for projectiles and propellant charges

Cannon/Munitions

Modular propellant charges

Scatterable mine "action rounds"

Extended range scatterable mine and SADARM projectiles

Passive IR CLGP

Remote or automatic fuze setting

Sliding breech block mechanism compatible with modular charges and automatic primer feed mechanism

Low Potential Concepts

During the course of the concept study, a number of ideas were advanced and eventually rejected for one reason or another. While there may be other battery weapon concepts which might warrant implementation of the rejected ideas this is considered unlikely, since a broad spectrum of concepts was discussed during the short but intensive concept formulation period. Following is a summary of the rejected approaches:

| Rejected Approach | Comment |
|---|---|
| a. 1,000-hp engine | Engines over 600 hp are not needed since cross-country mobility requirements could be met with available hp/ton ratios of 18 or less. |
| b. Unarmored SPH | While tactics and concepts were generated to maximize survivability by avoiding counterbattery fire, it is nevertheless believed that armor protection, roughly equivalent to the M109, is essential. |
| c. Steel or hybrid armor for SPH | No particular advantage was found in the use of either steel armor or nonmetallic armor (such as KEVLAR) in lieu of aluminum. (However, a nonmetallic armor giving partial protection to an unarmored ARV may be advantageous.) |
| d. New SPH turret on an existing tank chassis | Limitations on performance and effectiveness outweighed the possible advantages of using an existing chassis. |
| e. Fire-on-the-move | While this approach could theoretically lead to improved survivability, there are serious design problems in balancing a cannon whose center of gravity is so far from the trunnions. In effect, every round fired would be a first round and no fire control system thus far conceived will meet the accuracy requirement. In addition, a stop, shoot, and scoot mode of operation appeared to offer all of the survivability advantages that might accrue with fire-on-the-move. |

**f. Wheeled SPH**

Wheeled SPH were rejected since it appeared that an armored, wheeled vehicle would lead to excessive complexity and size such that its potential advantages in increased RAM would be lost.

**g. Positive pressure NBC protection**

From a design standpoint, it appeared feasible to provide positive pressure NBC protection for any of the new concepts or for the maximum product-improved M109. However, internal contamination from off-loaded projectiles and propellant charges was considered a serious problem. Adding a self-contained decontamination capability was not practicable. Therefore, hybrid NBC protection was provided for the SPH and the ARV.

**h. Spurt fire**

From a design standpoint, it is possible to provide a spurt fire rate of three rounds in 10 seconds and, in fact, a 155mm system has been demonstrated. In addition, six rounds in two seconds has been demonstrated for 105mm artillery weapons. However, for the targets under consideration, none would probably be defeated by a 3-round burst.

i. Screw block breech mechanism — This type of breech mechanism has strong self-sealing advantages when used with bagged or combustible case propellant charges. However, it operates slowly compared to a sliding breech block, and it is less compatible with automatic ammunition loaders and rammers.

j. Propellant charges with metal cases — Rate of fire and ammunition handling requirements could not be met by using bagged charges as in current 155mm systems. Metal case charges were briefly considered but rejected because of case disposal and gas fume problems within the SPH and negative impact on the rate of fire.

k. Extended range (37 km) CLGP — While both Class IV and Class V concepts evaluated extended range, no concept was developed for an extended range CLGP. (Their length of approximately 8 feet made them difficult to load and handle.)

Tasks Needing More Emphasis

During the course of the concept study it became apparent that a number of tasks needed additional emphasis; however, because of the limited nature of the effort, these tasks were not pursued as fully as desired. In retrospect, had the work been more comprehensive, it is not self evident that the overall results would have been materially affected. However, future efforts should include increased emphasis in selected areas to reduce the risk and to assure that optimum concepts are developed.

Specific areas needing additional attention are:

a. Cannon tube temperature buildup and cooling - The tubes of the M185 and M199 cannon have temperature limitations. The final determination of temperature limitation is a complex assessment and depends upon the initial condition of the projectiles and propellant charges, firing rates, tube design, and cooling characteristics. Propellant charge thermal input is a key parameter and is highly dependent upon maximum flame temperature and the use of additives to reduce heat transfer. Current mathematical models which predict bore temperature for the M185 or M199 cannon are inadequate when considering the higher rates of fire or intermittent burst fire used in Class II and III concepts. Conceptually, artificial cooling was considered and appears to have good potential. This was based on utilizing the hydraulic fluid in the concentric recoil mechanism as a means of transferring heat buildup to an external radiator where it could be exchanged to the atmosphere. It is recommended that improved mathematical models be developed to adequately analyze the thermal buildup in cannon tubes and to assure that key design parameters can be identified for higher rate of fire systems.

b. Use of heavy expanded mobility tactical truck (HEMTT) - During the latter part of the study it became known that TARADCOM was working on a HEMTT replacement for the M813. The advanced development program has progressed to the testing phase with the following options under evaluation:

  Straight frame truck with candidates developed by PACCAR and MAN in West Germany.

  Articulated frame truck developed by Lockheed/Oshkosh.

Results of the ASES concept effort indicate that the HEMTT has potential as a wheeled ARV, especially when considering the shoot and scoot tactics employed in the Class II and III concepts. The HEMTT as eventually developed will probably be an 8 x 8 truck with a 10-ton payload. It is recommended that future efforts include evaluation of the HEMTT in both roles.

c. Spread battery concept as a means to increase survivability - This survivability technique was frequently discussed during the study; however, no spread battery concept was developed. As envisioned, the basic idea is to confuse Soviet counterbattery radar and target acquisition devices by spreading the battery such that a minimum of 200 to 500 meters is provided between any two weapons. Combined battery fire would be programmed among the weapons so as to confuse Soviet counterbattery radar and increase their TLE. If their TLE is increased to 300 to 500 meters, it appears that our weapons would become almost invulnerable to counterbattery fire. It is recommended that future efforts explore this high potential concept.

d. Artillery doctrinal changes to reduce ammunition resupply problems - Ammunition resupply is beginning to get the attention that it has long deserved. However, in evaluating the total rounds fired, a doctrinal question is immediately raised. Referring to results of one of the artillery force simulation model (AFSM) runs when analyzing the Class I concept, it appears that approximately 18,000 rounds of 20,000 rounds fired by three battalions in a 24 hour period made little contribution in defeating or destroying enemy targets. The question is raised, "If these 18,000 HE & ICM rounds contribute so little to the battle, why fire so many?" If the number could be reduced, such as by one-half, ammunition resupply becomes much less a problem. However, ammunition resupply is still a manpower intensive area and needs considerable effort even at lower expenditure rates. It is recommended that target servicing doctrine be re-evaluated to determine whether it is reasonable to reduce the number of HE and ICM rounds fired.

e. RAM assessment and improvement -
Increased RAM is a critical element of the ESPAWS program. However, substantiating claims for improved RAM is a difficult task and needs experimental testing to validate conceptually higher values of MMBF and MRBF. Techniques such as redundant design, deregulated components, and overdesign are obvious approaches to significantly improve RAM in order to reach the desired improvement factor of three or more. Another approach with high potential is the STE/ICE program which, for the first time, will provide the crew chief with direct, easily readable information in terms of specific preventive maintenance required to keep the vehicle serviceable. It is recommended that this approach be given high priority to alleviate current RAM deficiencies.
Similarly, the incorporation of Air Force multiplexing technology appears to have a high potential to increase RAM and solve other problems in the distribution of electrical power, communications, and data transmission within the SPH. Its capability to reduce bulky, trouble-prone wiring harnesses to a manageable size is self-evident. It is recommended that multiplexing be pursued to determine its potential payoff in increasing RAM by developing an integrated fire control system, and an on-board, integrated test and diagnostic system. State-of-the-art development and cost implications should be concurrently pursued.

## Weapon Stability at High Rates of Fire

### Objective

The objective of this task was to evaluate the dynamic firing response of a SPH in order to answer the following questions:

1. "What is the maximum recoil force permissible without requiring a

rear firing spade and muzzle brake?", and

2. "What is the maximum firing rate permissible based upon the settling time of the howitzer?"

Approach

Two mathematical models were developed to analyze the transient response of a SPH for one round of fire. A horizontal analysis model (figure 80) examined the overall recoil movement while firing. The rod pull resulting at various recoil distances was determined and the horizontal force acting upon the tracks at each recoil length was calculated. A vertical analysis model (figure 81) examined the verticle displacements of the center of gravity (cg) and the rotational displacements about the cg. The forcing functions in this model were the breech force and the rod pull generated by the horizontal model. The outputs of the model were the vertical and the rotational displacements for analysis of the restrictions they place on high rates of fire.

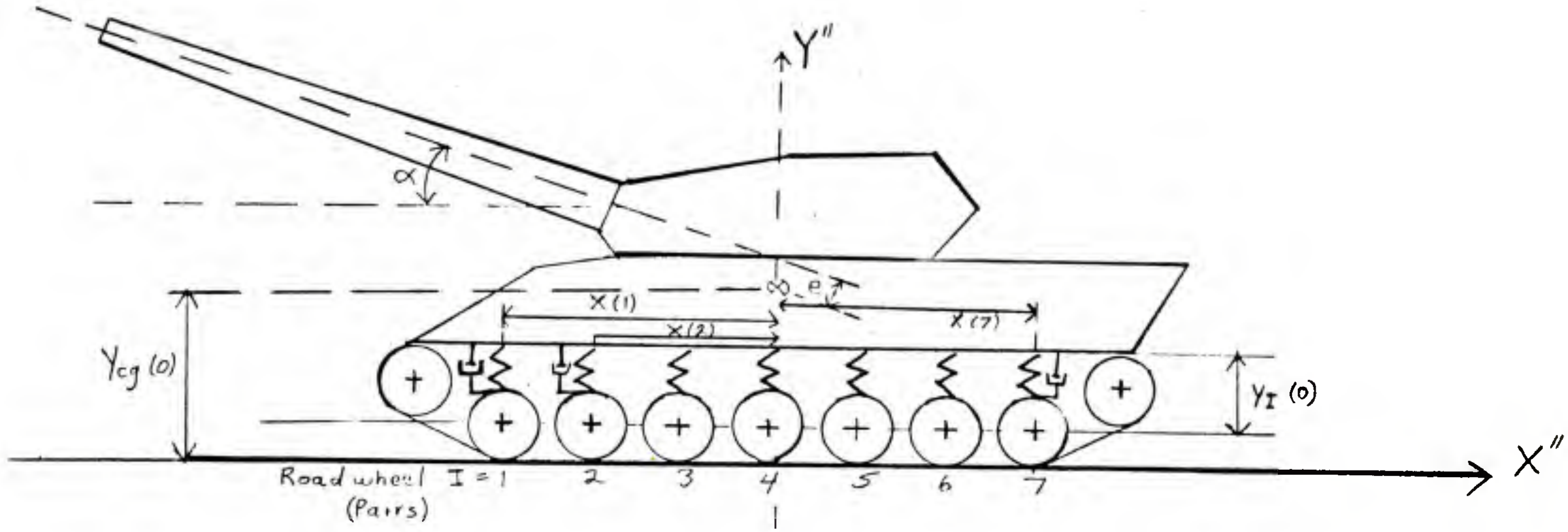
The horizontal model evaluated the effect of firing including both the movement of the recoiling parts and the secondary recoil of the chassis. The model simulated the breech force, B(t), on the recoiling parts and the rod pull, R(t), including both its effect of absorbing the firing reaction and its action upon the chassis to cause secondary recoil. The spring and damping characteristics of the suspension system were also simulated. A limiting value of track resistive force was established which was analogous to a coefficient of friction of about . 7.

A depiction of the vertical analysis model showing the chassis, relative location of the road wheels, cg, and spring-damper elements representing the suspension system and the track ground support is shown in figure 81. Since the program modeled planar motion only, each pair of road wheels was lumped into a single rigid body having twice the mass. The spring and damping characteristic curves for each road wheel were similarly doubled. This figure also gives the inertial properties and body locations used in the model.

In the computation of this program, the howitzer was initially considered to be at static equilibrium as supported by the suspension system of road wheels 1 through 7 with damping on wheels 1, 2, and 7. When the weapon fired, and as the chassis rocked backward and rebounded, the program simultaneously solved the basic equations of motion for the vertical movement of the cg and rotation about the cg.

Evaluation

The first step was to determine the maximum rod pull (and corresponding recoil length) permissible without using rear spades. That is, determine the maximum permissible horizontal force not exceeding the tractive force of the howitzer.




**VEHICLE CONSTANTS**

e Elevation = $0^{o}$ - 35.48
e Elevation = $30^{o}$ - 14.38

| | |
|---|---|
| X1 = 75.5 | X5 = -30.0 |
| X2 = 48.7 | X6 = -60.0 |
| X3 = 22.5 | X7 = -83.7 |
| X4 = -4.0 | |
| Y1 = 12.41 | Y5 = 12.56 |
| Y2 = 12.45 | Y6 = 12.60 |
| Y3 = 12.49 | Y7 = 12.64 |
| Y4 = 12.52 | |

Total weight = 63,000 lbs.
Weight of recoiling parts = 6508 lbs.
Total sprung mass = 143.18 lbs. (55267.5)
Spring constants:
#1, 2, 7, = 840. lbs./in.
3, 4, 5, 6 = 601. lbs./in.
Damping coefficient = 520. lb-sec/in.

Figure 81 Vertical Analysis Model

The basic configuration was taken from drawing no. 10955693 (Operational and Mechanical Characteristics/SPH-M109). The configuration was then modified to account for the increased mass and inertia of the M199 cannon. Estimates of the inertial properties and suspension system parameters were also taken from the drawing. In addition to the parameters given in figure 80, the following assumptions were made.

a. The secondary recoil of the chassis was not permitted to exceed 5 inches which is representative of typical firing conditions.

b. The maximum tractive force of the howitzer was . 7 to 1 (or 70%) of the total weight. (In order for the howitzer to remain in place when firing, the maximum horizontal force could not exceed 441, 000 lbs/in. )

The results of the horizontal analysis evaluation are shown in figure 82. Where maximum horizontal force occurred (zero degree azimuth and zero degree elevation), a recoil length of 15 inches (rod pull = 150, 000 pounds) generated a maximum horizontal force of 58, 000 pounds. When a 20-inch recoil was used, (rod pull = 120, 000 pounds) the maximum horizontal force generated was 41, 000 pounds. The horizontal force for a 15-inch recoil at 30 degrees elevation was approximately 45, 000 pounds. As is shown in figure 82, the maximum payoff in force reduction results when increasing the recoil from 15 inches to 20 inches, although a substantial reduction is also evidenced in the 20-25-inch increment.

It was concluded that a rigid mount weapon would transmit too high a force to the chassis and therefore a recoil mechanism would be required to provide the desired characteristics. (At zero degree elevation, the rigid mount system generated a maximum horizontal force of 400, 000 lbs/in—a force approximately seven times the total weight of the SPH. ) Based upon the foregoing evaluations, a stability analysis was made to determine the settling times of the howitzer and the effects they have on rates of fire. Although the same howitzer was modeled and the same parameters were used, the following different assumptions were made.

a. The forcing function of howitzer motion for each run corresponded to each distinct recoil length and angle of elevation used in the previous runs. (Recoil force was 120, 000 pounds for a 20-inch recoil length. )

b. Rearward motion of the howitzer was not considered except for the effect it had on generating the forcing functions referred to above.

Figure 83 indicates that when firing at zero degree azimuth and zero degree elevation, and for recoil lengths of 15 inches to 35 inches (increments of 5 inches), the mean time to dampen out vertically is 1. 85 seconds (std dev = . 134) with a worst case of 2. 0 seconds for the shortest recoil length (15 inches) and a best cast of 1. 7 seconds for a recoil length of 35 inches. The rotational motion damped out at a mean

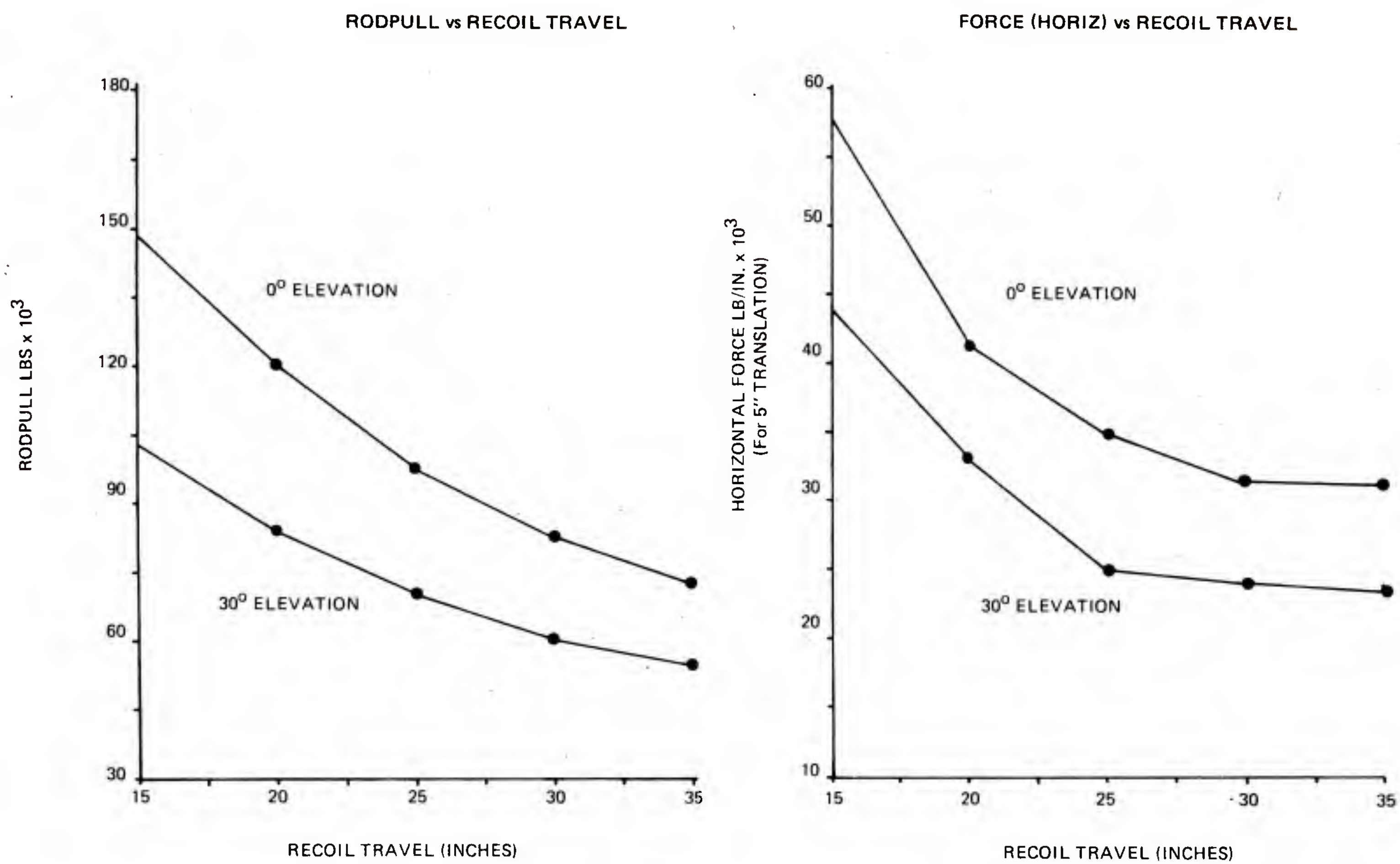
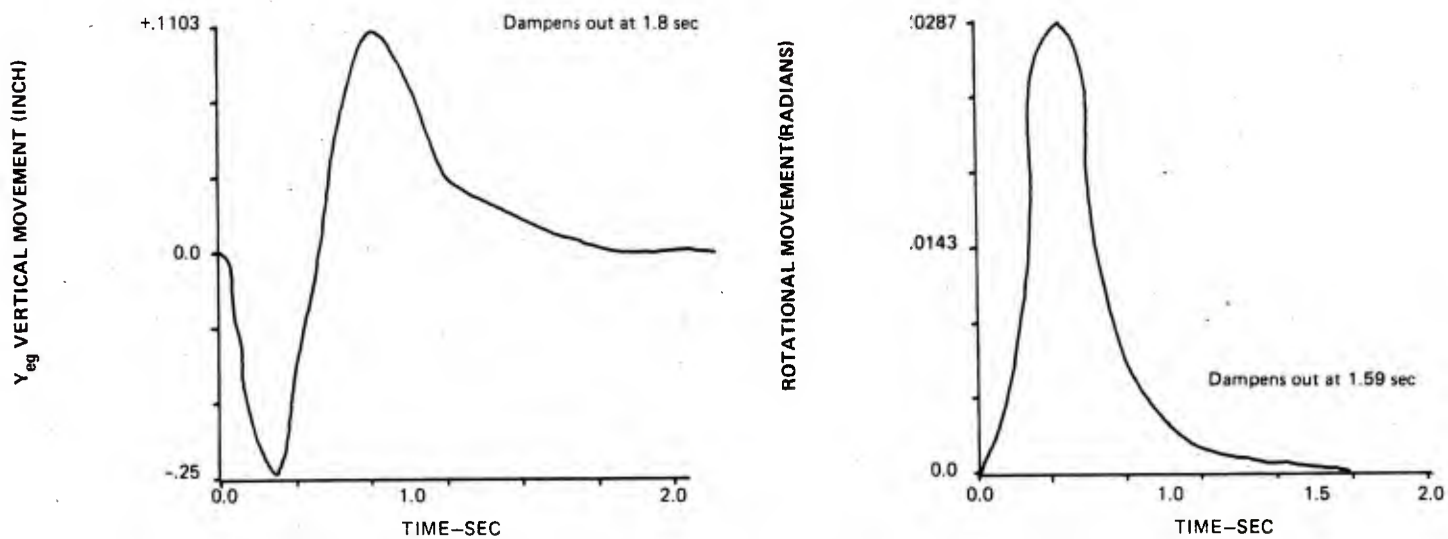



Figure 82 Recoil Travel Versus Rod Pull and Horizontal Force




THESE GRAPHS REPRESENT 120,000 LB RODPULL; 20-INCH RECOIL LENGTH; 0° ELEVATION

BEST CASE = 55,000 LB RODPULL; 35-INCH RECOIL LENGTH; 30° ELEVATION
WEAPON DAMPENED AT 1.7 SEC VERTICALLY; 1.3 SEC ROTATIONALLY

Figure 83 Vertical and Rotational Displacement Time of 1.588 seconds (std dev = .008) with a worst case of 1.6 seconds for a recoil length of 15 inches and 1.58 seconds for a recoil length of 35 inches.

The following conclusions were reached. A recoil length of 15 inches at the worst case condition (zero degree elevation) resulted in a force which caused the howitzer to move backward. At 30 degrees elevation, a 15-inch recoil was marginally acceptable. It is therefore recommended that a 20-inch recoil length be used, as the forces generated under this condition fall below the maximum tractive force for any elevation angle.

It was further concluded that in the worst case condition the howitzer would dampen out in just under two seconds; therefore, the vehicular stability would be such that up to 30 rounds per minute could be fired. At the recommended recoil length of 20 inches, the vehicular stability would permit rates of fire of up to 35 rounds per minute.

## Communication and Data Transmission Requirements

### Basis for Requirements

The mission of the field artillery is to destroy, neutralize, or suppress the enemy by cannon, rocket, and missile fires and to integrate all supporting fires into the combined operations. On the modern battlefield, the commander's ability to integrate the elements of the combined arms team into effective combat power is highly dependent on his ability to communicate.

The establishment of effective channels of communication has never been a simple matter but has been effectively accomplished in the past by way of conventional AM and FM radio and field telephone nets. Upon occupation of a position, initial communications are by radio. However for security and reliability purposes, it is considered good practice to establish wire links wherever and as quickly as possible and to use them to the greatest extent possible. Although they are not necessarily intended to replace the radio nets they parallel, they do become the primary means of communications.

In the past, it was possible to remain in a given position for sufficient periods of time to consolidate assets in a relatively confined area and permit wire teams to lay the required nets. However, on the modern battlefield, the need to disperse our assets over large areas and to frequently move in order to survive will make it difficult if not impossible to establish wire communications in a timely manner. Therefore, of necessity, we will be forced to switch our reliance from wire to radio nets.

Compounding the problem is that the modern battlefield is becoming more and more oriented toward automatic data processing systems such as TACFIRE and BCS. Such systems are far less tolerant of breaks in communications protocols and improperly maintained equipment than the present voice system. For example, on a noisy radio net, enough voice information for a given message may get through to allow the reconstruction of a useful message by the person on the receiving end. However, the same conditions may prove disastrous to digital communications. To date, the solution to the problem has been to rely on the present family of FM radios. Experience in TACFIRE operational testing and the recent series of HELBAT exercises give indication of the difficulties which may be expected with these radios. Add to this the proliferation of subscribers on a given net, the need to transmit ever increasing quantities of data as battlefields and supporting weapon systems become more complex, the transmission of both voice and digital communications over the same nets, the enhanced electronic countermeasure (ECM) capability of our adversaries, and so forth, and it becomes obvious that communications must be considered one of the most critical areas of investigation in the overall ESPAWS program.

In order to highlight the severity of the loading which may exist on these nets, the following paragraphs address the present system, the TACFIRE system and one potential configuration of the ESPAWS system.

Present System

Figures 84 through 89 depict the present radio nets with which the battery must maintain either direct or indirect communications in order to conduct fire missions. The figures indicate only those stations essential to the conduct of a fire mission; nonartillery stations on a given net are simply labeled as "other stations". Also, at the battalion (BN), nets in addition to those indicated will be found which serve as links to division artillery, target acquisition battery (TAB), and so on. Presently, all are voice nets and thus offer some flexibility in that if one net is busy an alternate route can be selected. Also, invariably, the radio nets are augmented with parallel telephone nets.

Listed below are the various nets and a description of the artillery related aspects of their use. Refer to figures 84 through 88 for the various stations on a given net.

1. F ( ) - Fire Direction Net. The direct support (DS) battalion (BN) operates three F nets designated as F1, F2 and F3. Three FIST teams and one battalion fire support officer (FSO) align with one battery and one F net. The F net is the primary net for the conduct of fire missions.

2. CF 1/2 - Command/Fire Direction Net. The DS battalion operates two CF nets designated CF1 and CF2 or CF and CF alternate. The CF1 is the primary net designated to carry command and control, intelligence, administrative and logistic traffic. It may be used to transmit fire direction traffic if required. The CF2 or alternate net

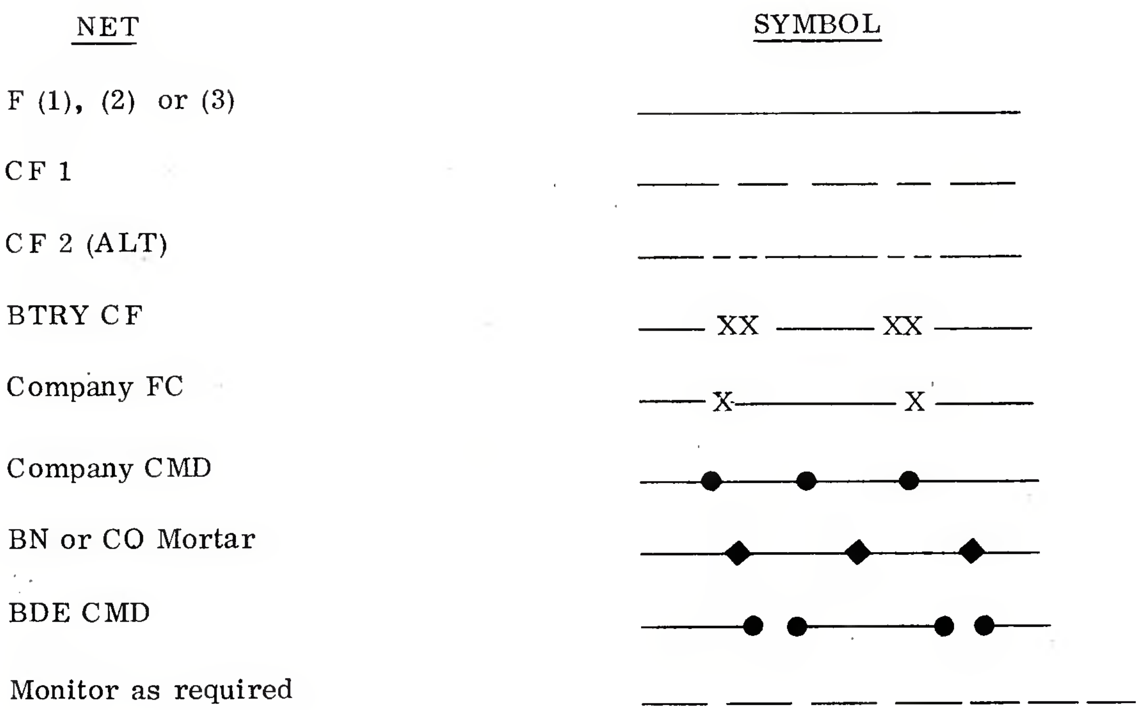



Figure 84 Legend for Radio Net Illustrations

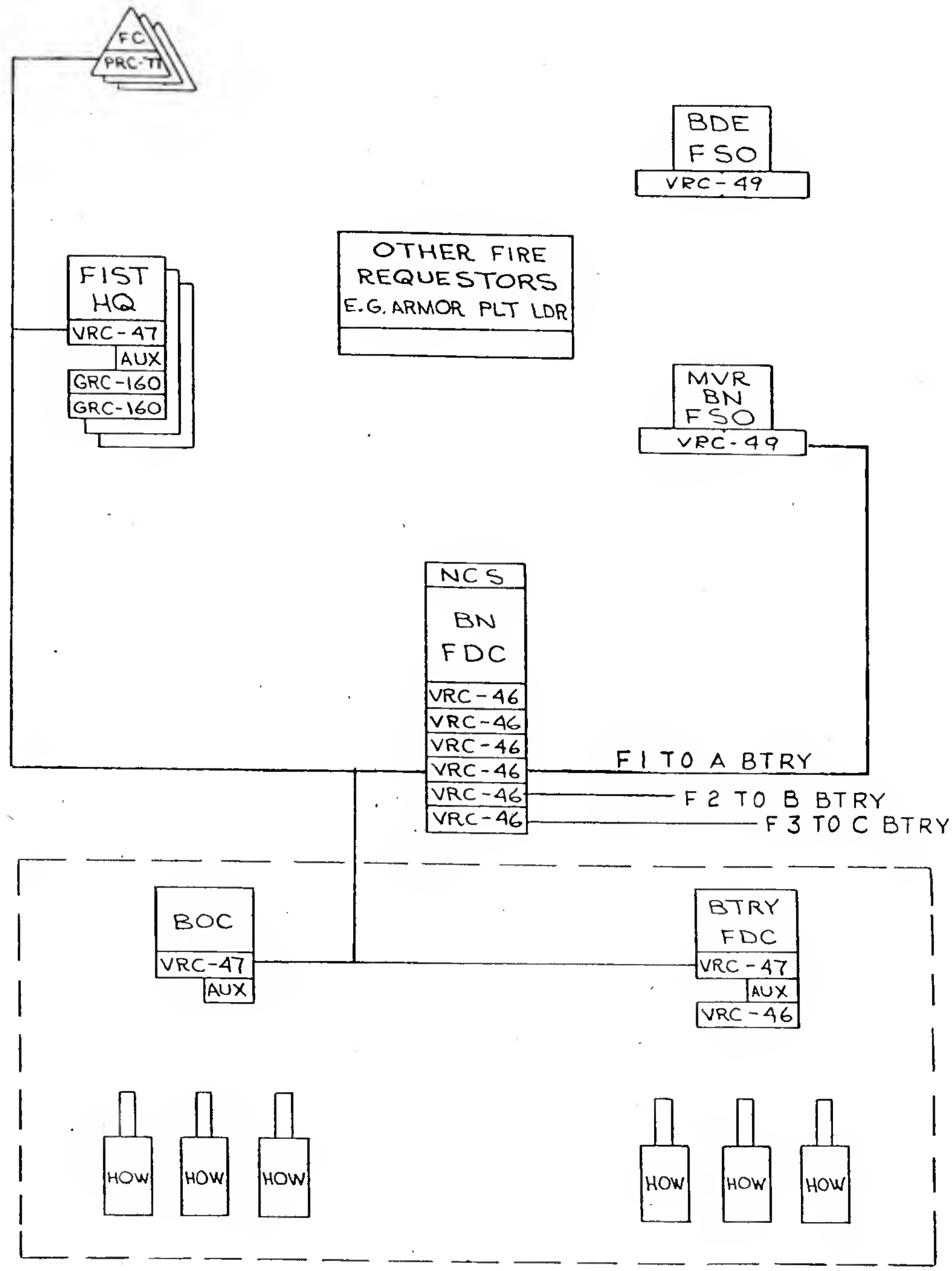



Figure 85 F( ) Net (Present System)

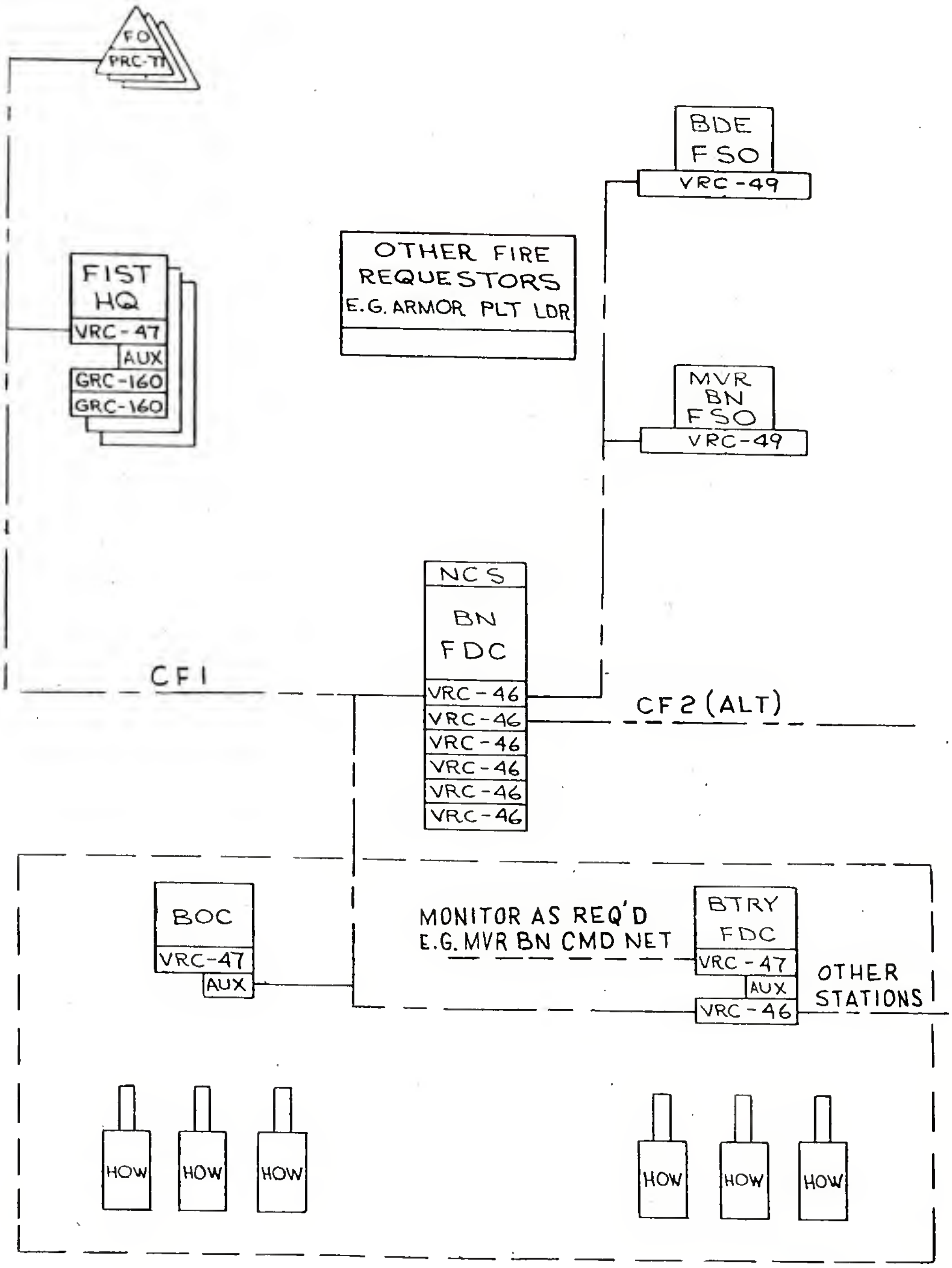



Figure 86 Battalion CFI and CF2 (ALT)
Net (Present System)

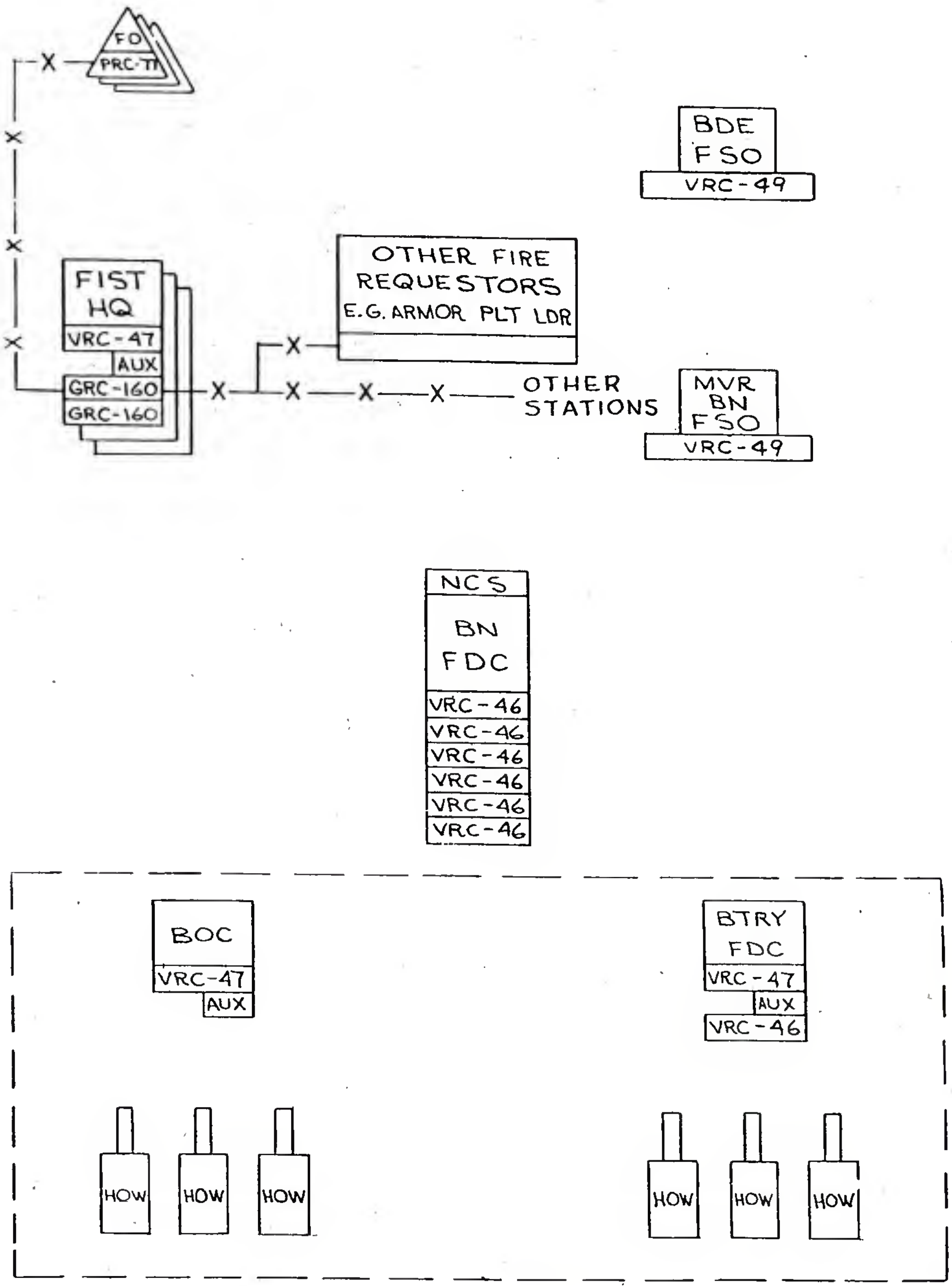



Figure 87 Company Fire Control Net

(Present System)

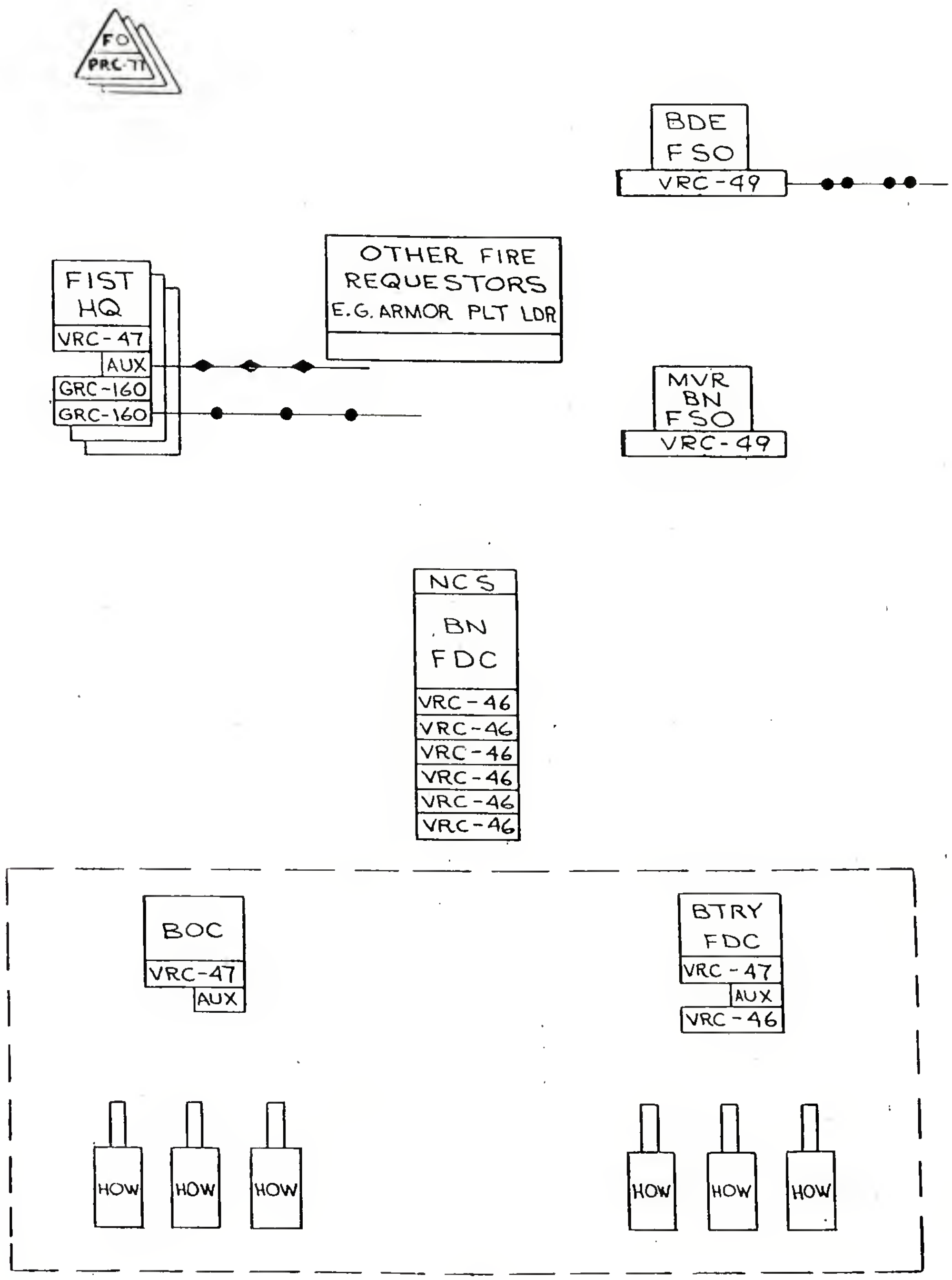



Figure 88 Additional Command/Control and Fire Direction Nets (Present System)

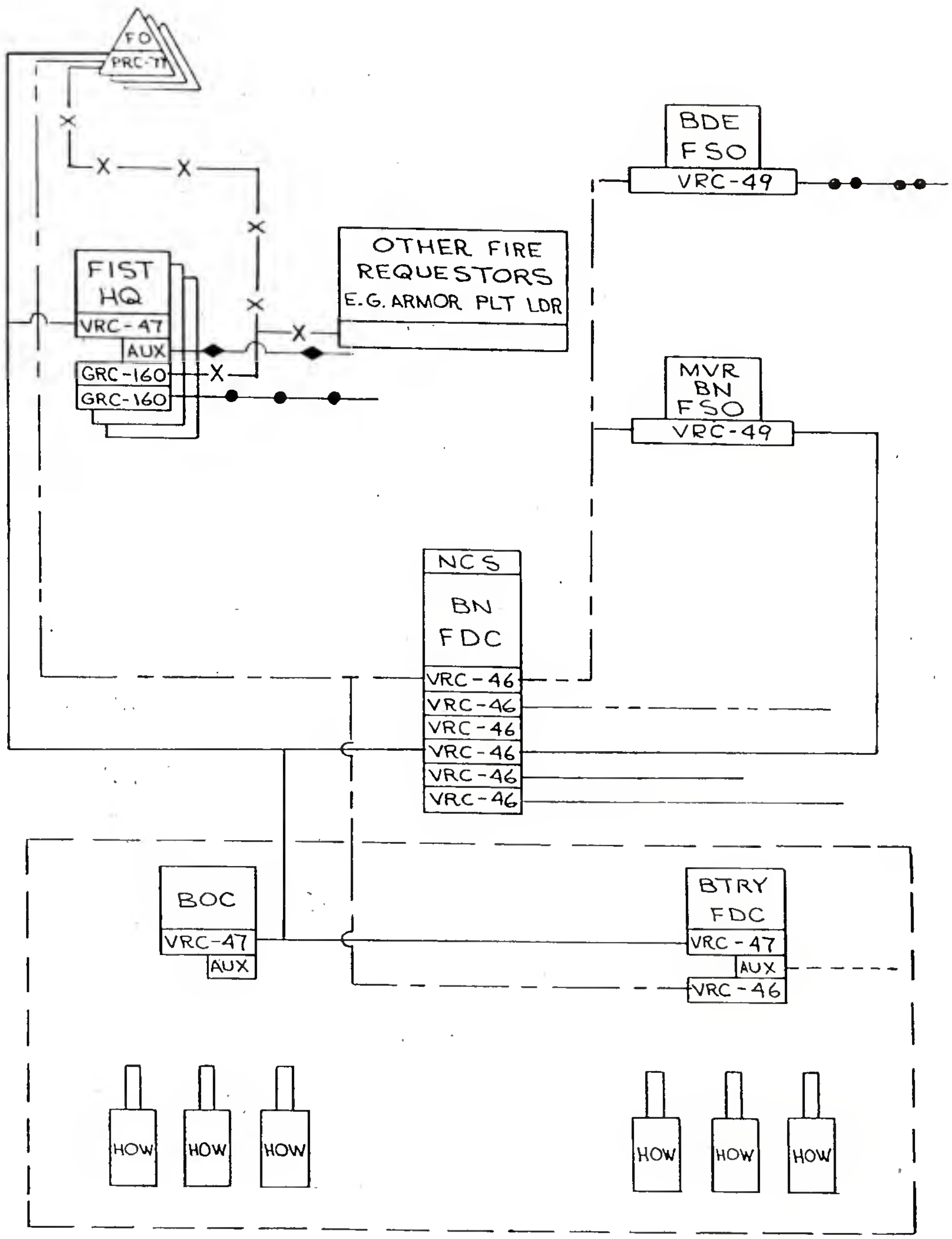



Figure 89 Composite Net Diagram
(Present System)

is designated to handle the overflow which occurs under extremely heavy traffic conditions.

3. CFC - Company Fire Control Net. The CFC net is the primary net over which FO's and other fire support requestors transmit calls for fire to the FIST headquarters. This net also provides the dedicated net required for laser guided munition missions.

4. CO CMD - Company Command Net. This net provides for direct communications between platoon leaders, the company commander and the FIST chiefs. It may be used for initial requests when the CFC net is busy.

5. BN Mortar Net - 4.2-inch battalion fire direction net over which the FIST team chief requests mortar fire.

6. CO Mortar Net-81-mm company fire direction net over which the FIST team chief requests mortar fire.

7. BDE CMD - Brigade Command Net. This net provides a means for interchange of fire support and intelligence information between the brigade (BDE) FSO and the maneuver brigade.

It is important to note that fire missions can be passed from the FO's or FIST to an FDC over any of three nets by voice (CF 1/2 or F ( ) ). Further, the FIST may receive fire requests from FO's or other requestors over either of two nets (CFC and CO CMD). As will be seen in the following paragraph, some of this flexibility is lost with the TACFIRE system.

TACFIRE System

The radio nets in the TACFIRE system are basically the same as those in the voice system. Figures 90 through 95 depict the TACFIRE system. It is assumed that the artillery will adopt the 8-gun battery concept and that radio communications in lieu of the present wire link from the battery FDC to the guns will be a part of the system. Figure 94 shows the added battery command/fire direction net. The most significant difference between the TACFIRE and present nets is that the F ( ) and CFC nets which were previously voice nets new become dedicated digital data nets. Whereas with the voice system, fire missions could be routed over any one of several nets under emergency or heavy traffic conditions, such is no longer possible without prior coordination with the net control station (NCS). With FIST teams, the maneuver battalion FSO, the battery FDC and battery operations center (BOC), the battalion FDC, and possibly individual platoon FO's vying for use of the single F ( ) net; and with no protocol other than to listen for a clear net before transmitting, clashes are inevitable. In addition, frequent relocations will preclude the use of telephone nets.

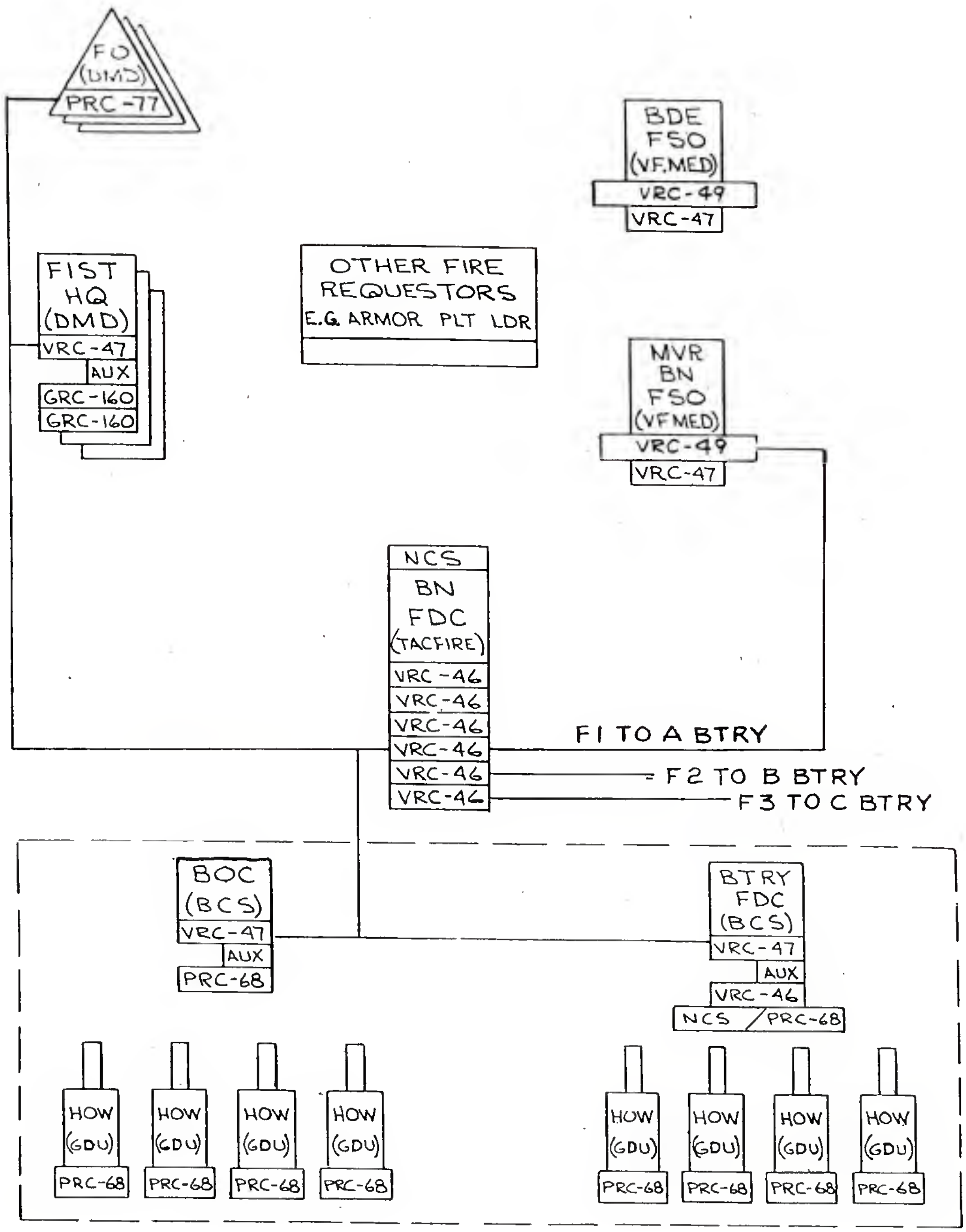



Figure 90 F( ) Net (TACFIRE System)

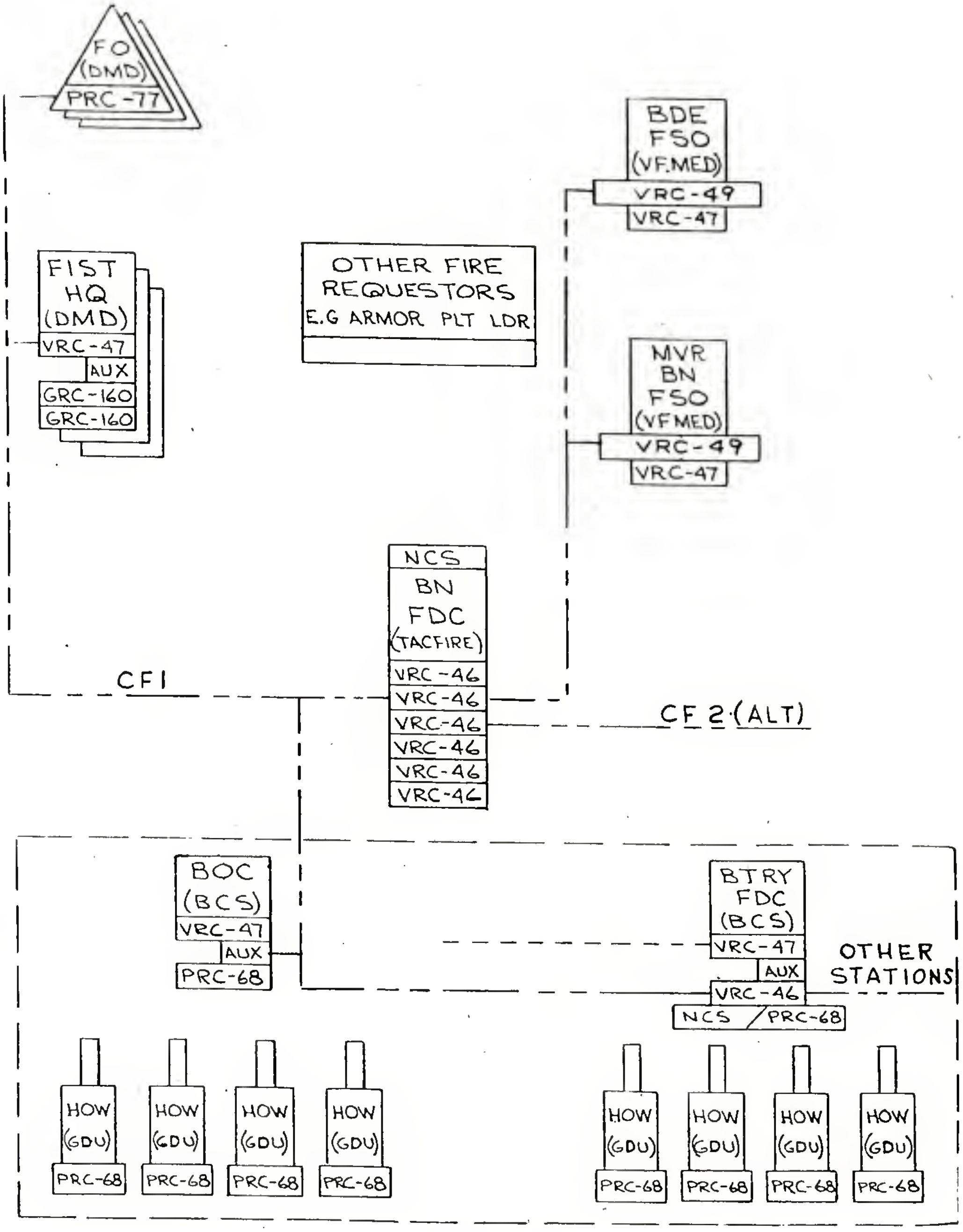



Figure 91 Battalion CFI and CF2 (ALT)
Net (TAC FIRE System)

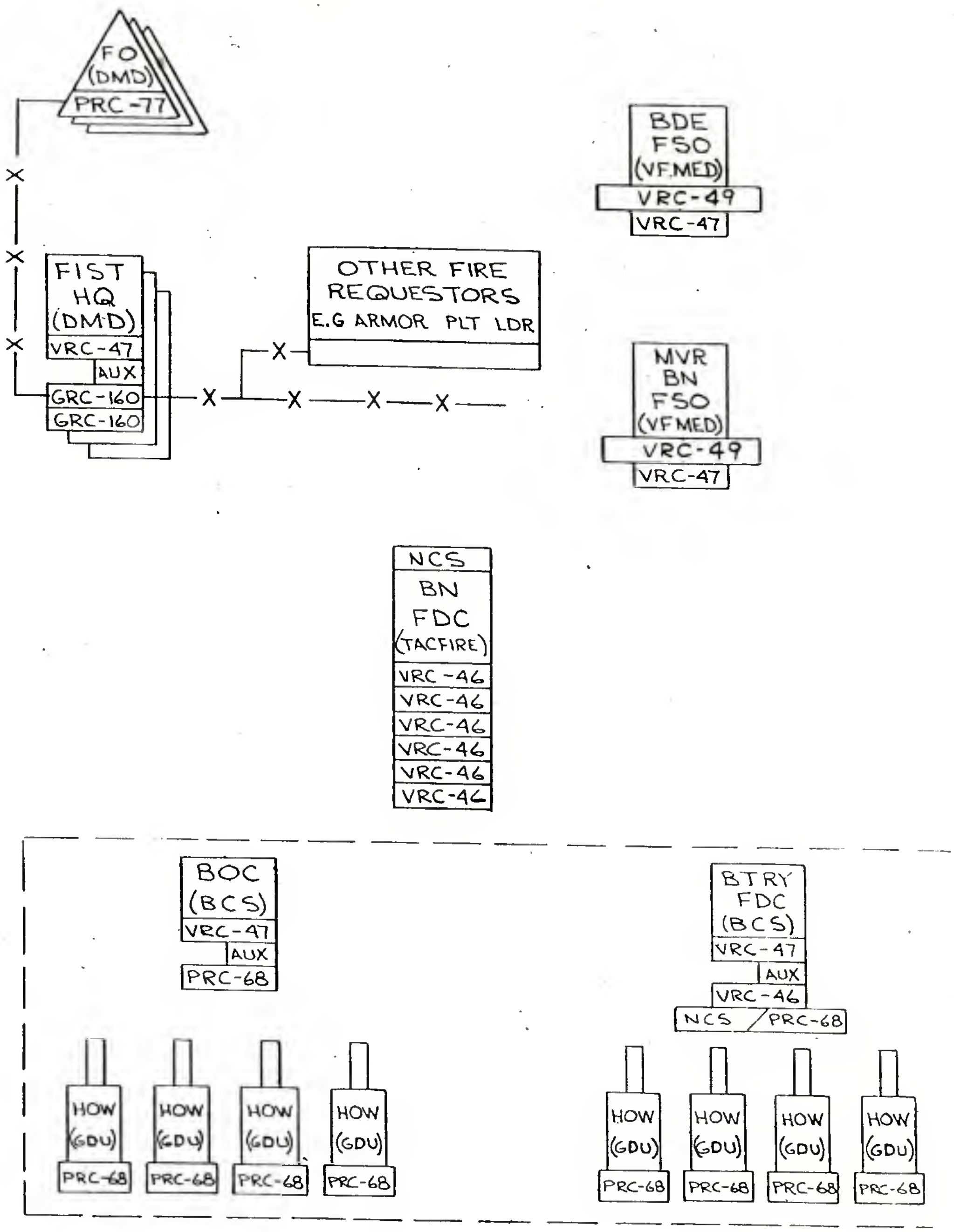



Figure 92 Company Fire Control
Net (TACFIRE System)

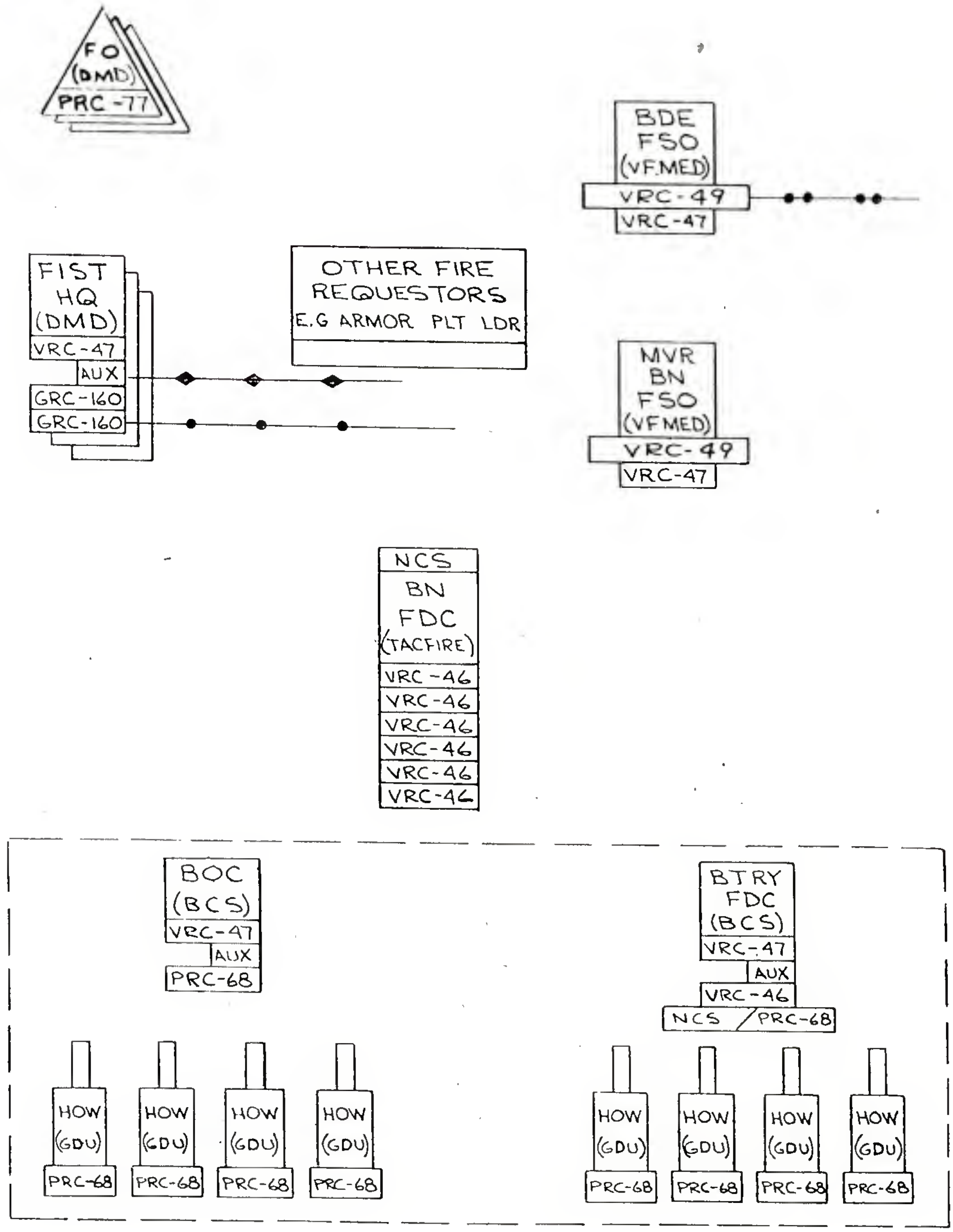



Figure 93 Additional Command/Control and Fire Direction Nets (TACFIRE System)

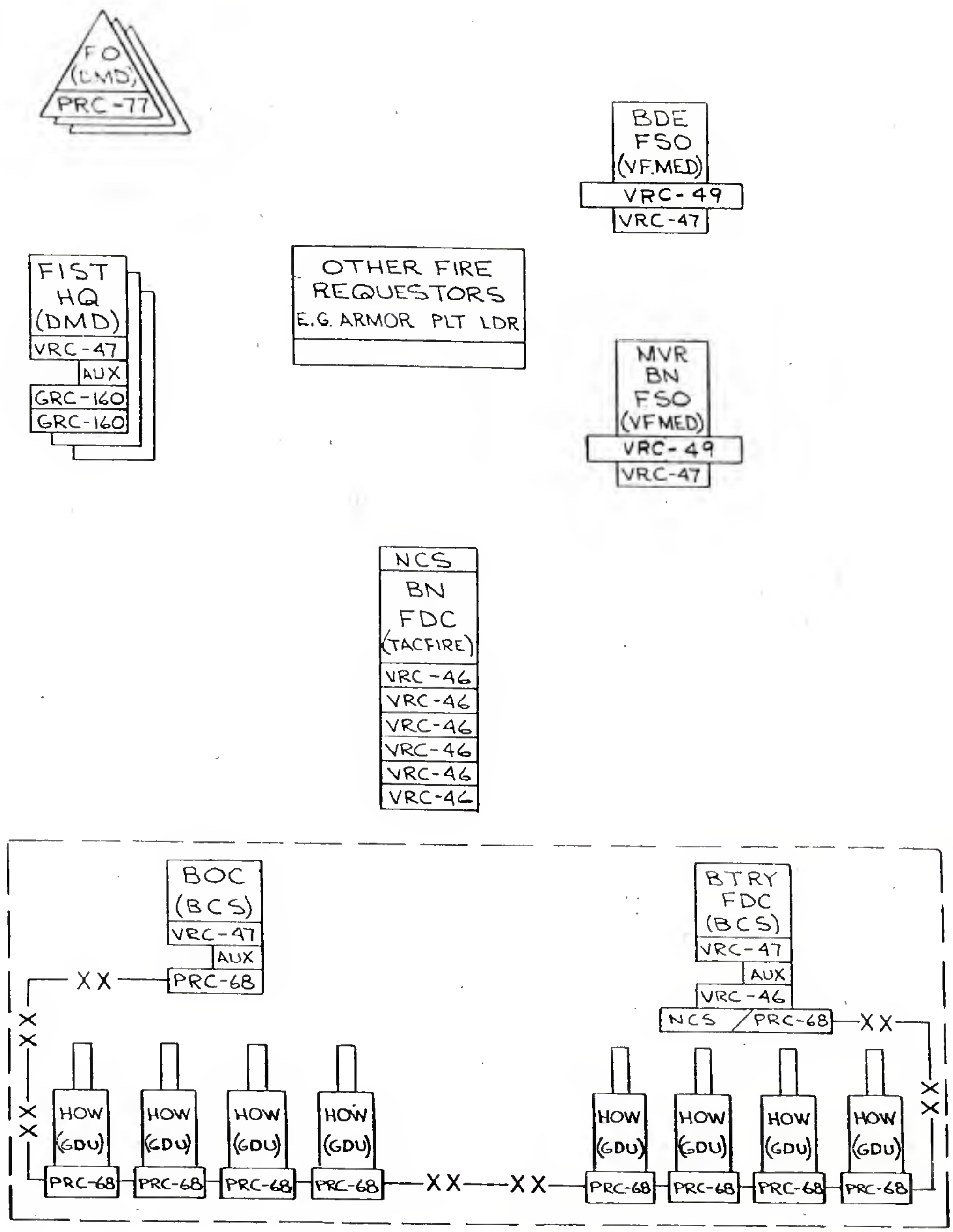



Figure 94 Battery Command Fire
Direction Net (TAC FIRE System)

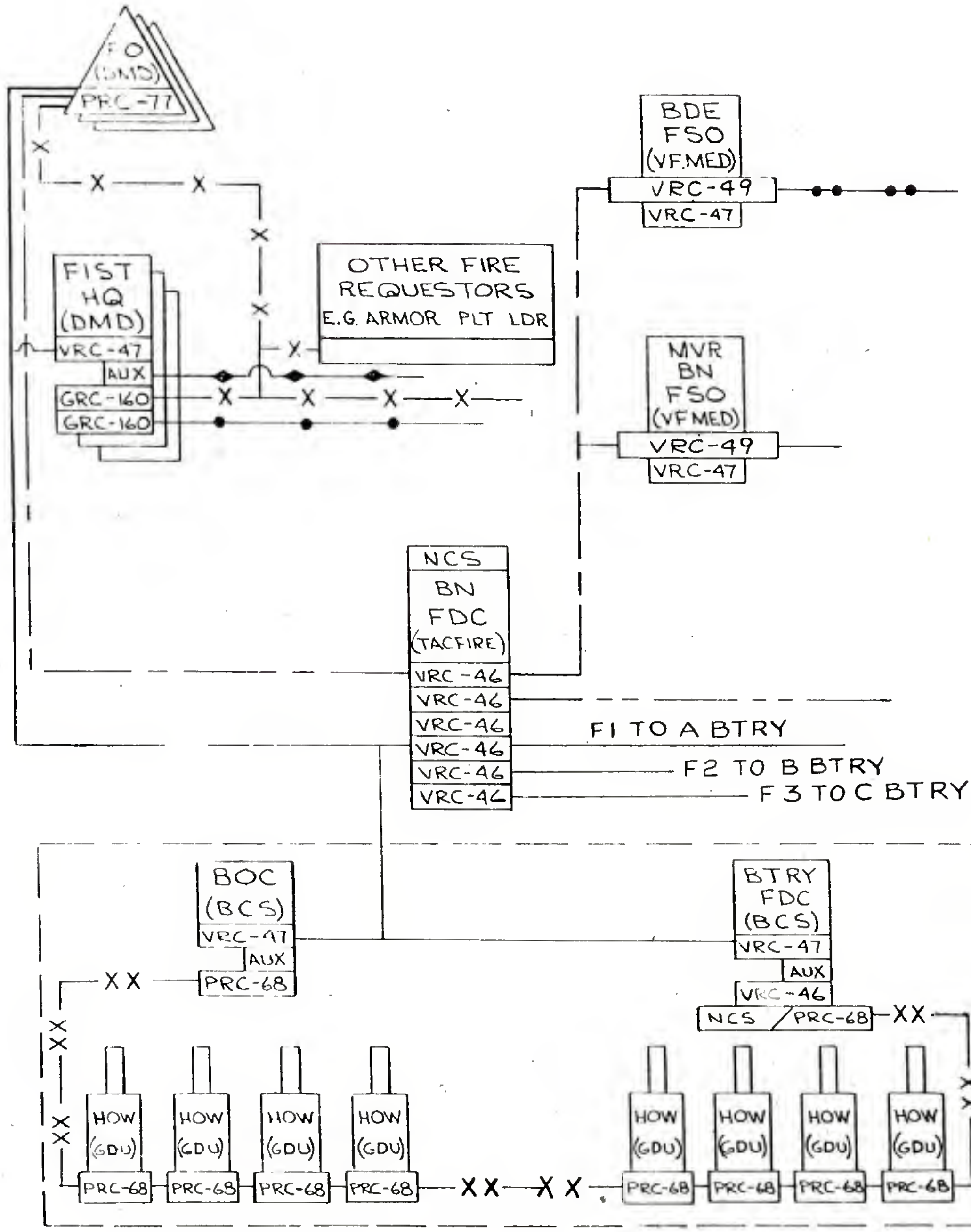



Figure 95 Composite Net Diagram
(TAC FIRE System)

Thus, not only does the radio system become less flexible and require more rigid conformance to operating procedures but an alternate route of communications is lost. The overall effect is to further stress an already overloaded system.

Proposed ESPAWS System

The proposed ESPAWS system uses the TACFIRE radio nets but has the additional requirement to establish a link between the individual gun (or guns) and the FO. This provides a capability to conduct fire missions directly between a gun(s) and an FO after coordination with a battery or battalion FDC. Since the only net common to all of these elements is the F ( ) net, it is the most logical choice on which to place the additional load of eight guns. With this capability and with a weapon potentially as responsive and lethal as that proposed for ESPAWS, the conduct of as many as eight simultaneous missions per battery becomes a possibility.

At this point, it is not anticipated that any concept being considered will have a more adverse impact on the communications system than another since all basically use fire and forget types of munitions. Thus, once a round has been fired, it is no longer necessary to maintain communications with the FO as would be the case if active terminal homing munitions were used.

Based upon the foregoing considerations, it is evident that the communications requirement will become more demanding with ESPAWS. In view of the demonstrated inability of the present radio system to perform adequately during TACFIRE and HELBAT testing it is apparent that it will not be capable of supporting the ESPAWS concepts.

Potential Solutions:

Position Location and Reporting System/Joint Tactical Information Distribution System (PLARS/JTIDS) Hybrid

The PLARS/JTIDS hybrid radio system is based on ultra high frequency (UHF), time division multiple access (TDMA) techniques. Jam resistance is provided by use of frequency hopping and spectrum spreading. Security is provided by way of an integral communications security capability. It is a data system having no voice capability.

The hybrid consists of interfacing of the two separate systems (PLARS and JTIDS) to assure interoperability on the battlefield. Initially each program was being independently pursued; PLARS basically as a positioning system with some data transmission capability and JTIDS the opposite. In the hybrid system, the intent is to deploy JTIDS terminals from brigade level rearward and PLARS from brigade level forward. Thus for ESPAWS purposes, PLARS may be considered the candidate system.

The data handling capacity of the system is extremely scenario dependent, e.g., the number and type of subscribers, whether they are in a position location or data transmission mode, and so on, all affect data rates. Based upon the information presently available, thorough analysis of the system is not possible. Studies to date indicate that PLARS will support ESPAWS.

Packet Radio

The packet radio uses PLARS/JTIDS technology to provide antijam and electronic counter-countermeasure (ECCM) capability. It is basically a digital data system although a voice capability is possible. Each user terminal must be interfaced with a packet radio unit. The packet radio unit then stores the message, forms it into packets of equal length and transmits the information to its destination. It offers definite advantages over PLARS in that it services more users (several thousand), has a higher data rate, avoids channel idling by non-active users and is randomly accessible. The system would provide a fully automated network management structure thereby avoiding the data clashes which could be expected with today's radios and their total lack of a protocol capability. An additional advantage of the system is that, unlike PLARS, it is non-nodal in nature and thus the loss of a master station does not defeat the total system. The applicability of this system requires significant analysis before any conclusions can be drawn.

Smart Single Channel Ground and Airborne Radio System (SINCGARS)

SINCGARS is the next generation military radio system. Unlike the previously discussed systems, this is the only one for which there is an approved requirement. It is being designed to interoperate with the present family of radios. It provides an ECCM capability through frequency hopping, and handles secured transmissions through separate communications security equipment. It offers 2,320 channels versus 912 at present. Voice, quasi-analog, and digital data can be transmitted. The basic SINCGARS radio is a "dumb" unit in that it is essentially a push-to-transmit radio. The smart SINCGARS consists of the integration of an intelligent controller using packet techniques with the basic SINCGARS equipment. This, in effect, would provide fully automatic network operation with all the protocols necessary to avoid current data clashes. In view of the approved requirement for SINCGARS and the fact that the controller could be a peripheral device, this appears to be the most practical approach to the ESPAWS problem. One disadvantage is that an additional channel would be required for voice communications.

Miscellaneous Systems

Development work is in progress on an "Integrated Tactical Communications System" and on satellite communications (SATCOM). Both of these are high-level systems and are apparently appropriate for communications over extremely wide areas (division and above). They do not appear to be applicable at the battery level where large numbers of users are communicating over relatively short distances.

Action Items:

1. Perform a quantitative analysis of ESPAWS communications requirements to support the qualitative analysis given in the Basis for Requirements paragraph above. The analysis must include such factors as time lines, message formats and lengths, message rates, numbers of subscribers, message routes, etc. The analysis should include both the present system and the fire control system proposed in the ASES. Particular attention should be given to special requirements which may be imposed by the various classes of concepts.

2. Arrange in-depth technical discussions with CORADCOM personnel to further evaluate potential application of developmental communications systems to ESPAWS. The evaluation should be based on information derived from Action Item 1.

Although the systems briefly described in the Miscellaneous Systems paragraph above do not appear to be applicable to ESPAWS, they should not be arbitrarily ruled out at this time. The concurrence of CORADCOM regarding the final disposition of these systems is essential to a thorough evaluation.

CORADCOM points of contact for further discussion are:

a. INTACS - The Integrated Tactical Communication System
Mr. J. Manno, AV (8)-995-4325

b. SINCGARS - The Single Channel Ground and Airborne Radio System
Mr. R. Rugarber, AV (8)-995-2110

c. Packet Radio - Mr. Graff, AV (8)-995-4346

d. PLARS/JTIDS Hybrid - Mr. H. Bahr, AV (8)-992-4251

e. Future HF Radio Systems - Mr. M. DiJulio, AV (8)-995-2340

f. SATCOM - Future Single Channel Tactical Satellite Communications System - Mr. S. Yauger, AV (8)-992-1461

## Special Study of Reduction of Delivery Error

### Background

In any future conflict our artillery will be vastly outnumbered; therefore, it must be more responsive and lethal than ever before. It is estimated that over 80% of the missions performed by direct support cannon artillery will be in the target servicing mode; that is, coordinated by a maneuver commander and his FO. It may be assumed that the majority of targets will be moving armored vehicles.

We anticipate that the enemy will possess counterbattery radars at least as effective as ours. The result is that our batteries will be rapidly and accurately located and will receive counterbattery fire within 3 to 5 minutes after firing their first round. Survival requires that we fire rapidly and move to a new position before receiving counterbattery fire. In addition, time consuming adjustment on target must be eliminated. Not only does adjustment warn the enemy of incoming fire, allowing him to assume a hardened posture, but it severly limits the amount of time available to fire for effect (FFE).

The above considerations demand that a new operational concept of target servicing be developed and applied if we are to perform the target servicing mission and survive. Two methods of achieving the required response and accuracy are outlined in the following paragraphs. Each has certain advantages and disadvantages, and each provides the required accuracy. The first method described is the Human Engineering Labortory battalion artillery test (HELBAT) method; so named because of its conception and demonstration during the HELBAT series of tests. The second method is the artillery registration and adjustment system (ARADS), currently under development at ARRADCOM.

### Scenario

The scenario assumed in the target servicing mode consists of an array of 3 to 10 armored targets in visual contact with the FO. A single SPH (Class II) will engage the target array with scatterable mines at a distance of 8 to 22 km from the FEBA. The howitzer will fire 18 rounds of 10 mines each in a period of 3 to 5 minutes and then, before counterbattery fire is received, move to a new location 500 to 2,000 meters from the initial firing site. It has been determined that if the mines can be delivered with an accuracy of between 50 and 80 meters circular error probability (CEP), the likelihood of killing an individual target in the array will approach unity.

### Statement of Problem

The baseline system (Class I) is not capable of attaining the required delivery accuracy. With that system at a range of 14 km, and with ideal target and FO location, delivery accuracy is on the order of 150 meters. When the "map spot" target and FO location errors currently experienced are considered, the total delivery CEP can easily increase to over 250 meters for a stationary target and over 500 meters for a moving target array. Reduction of such large errors requires FO coordinated adjustment on the target. These adjustment techniques waste time and rounds, give away our battery positions, warn the target of incoming fire, and allow it to harden or relocate. On the future battlefield, these adjustment techniques are unacceptable.

The problem at hand is how to deliver fast, accurate FFE without adjustment on the target. In order to inflict maximum damage and guarantee our survival, first round FFE accuracies an order of magnitude better than currently achievable are required. The HELBAT and ARADS methods appear to offer feasible solutions to the problem.

HELBAT Method

The equipment required at the SPH and by the FO is summarized as follows:

| SPH | FO |
| --- | --- |
| Position location | GLLD |
| Azimuth & elevation reference | DMD |
| On-board technical fire control | |
| Automated lay | |
| Digital communications | |

Once the FO is located by map spot along a probable avenue of approach, and a target's appearance is imminent, the procedure for reducing the delivery error begins. An aim point, a sufficient distance from the expected target location to prevent warning it of subsequent FFE rounds, is selected and a round is fired. The FO lases on the impact of the round and a "should hit"/"did hit" computation is performed. Since the SPH precisely knows its position, this has the effect of placing it and the FO on the same map grid. Corrections for nonstandard conditions such as meteorological (MET), muzzle velocity variations, howitzer and FO location errors, etc., are applied to the FFE volley. It is estimated that a delivery CEP of approximately 55 meters, including major error sources, can be achieved by this method (disregarding target location/prediction errors). (Target location/prediction errors and their effect on delivery accuracy are subsequently discussed.)

Advantages of the HELBAT Method

1. Minimal equipment is required by the SPH and FO.

2. Accuracy is achieved at low cost.

3. Viability has been established in HELBAT tests.

4. Registration remains valid for future firing missions assuming the FO does not relocate.

Disadvantages of the HELBAT Method

1. The FO is tied to a particular SPH or group of howitzers.

2. Each time the FO relocates, the procedure must be repeated.

3. The data obtained from the "did hit"/"should hit" computation can be applied only to SPH in the same geographic area and coordinated by the same FO.

ARADS Method

The special equipment required for this technique (in addition to that provided by the Class II concepts) is summarized below:

| SPH | FDC | FO |
|---|---|---|
| ARADS transponder/fuze | Position location | Position location |
| | ARADS antenna | |
| | ARADS processor | |

The ARADS system consists of an interferometer radar antenna and processor at the FDC and a transponder/fuze placed in the fuze well of a standard artillery round. When a round is fired, the antenna watches for the round at an angle approximately 30 degrees above the horizon. Upon intercepting the round, the transponder (in the fuze well) is turned on and provides accurate position and timing data at the intercept point. From this information, a "did hit" estimate is computed. Based on the "should hit"/"did hit" information, a linearized optimal Kalman filter in the ARADS processor computes optimal estimates of the critical flight parameters such as wind, muzzle velocity, gun pointing errors, lift and drag constants, and air density. These corrections are than applied to subsequent FFE rounds. ARADS data can be stored in the FDC or howitzer computer for application to later missions, and can be applied to other howitzers firing from the same geographic location and at similar ranges.

It is assumed that the MET and other critical flight parameters will remain valid for a reasonable period of time. Current estimates indicate that each howitzer would fire an ARADS registration round no more often than once every hour or two. The information obtained from each round is used to update the data base and is applied to all howitzers in the battery.

Accuracy estimates for the ARADS system indicate that a 50 meter CEP can be expected when target location/prediction errors are disregarded.

Advantages of the ARADS Method

1. Corrections can be applied to other SPH
2. Data need not be updated for every mission.
3. Does not tie a howitzer to a particular FO.
4. Can be used to improve accuracy of unobserved fire up to 60 km.
5. Registration round may be an FFE round.

Disadvantages of the ARADS Method

1. Requires special equipment at the SPH, FO, and FDC.
2. Higher cost.

Target Location/Prediction Errors

The delivery accuracies discussed thus far do not include moving target location/prediction errors. These represent a separate and unique set of variables which require detailed examination.

Past experience shows that delivery errors for the baseline system can exceed 250 meters for stationary targets and 500 meters for moving targets. A significant portion of the delivery error is related to target location and prediction errors. The major contributors to these inaccuracies are summarized below.

| Source of Error | Moving target | Stationary target |
|---|---|---|
| FO location | 50 to 100m | 50 to 100m |
| Target location/ prediction | 500 to 600m | 50 to 100m |
| MET+VE MPI & precision CEP | 140m | 140m |

The procedure utilized to predict a target's future position is a straight line extimate of velocity based on two or more position lasings by the FO. Errors are encountered in prediction since the position measurements utilized to estimate target velocity contain a finite error, which leads to some uncertainty in both the magnitude and direction of the target velocity vector. More importantly, there is no way to predict with any great certainty the direction or magnitude of target velocity after the final lasing. However, if it is assumed that the target array is moving toward the FEBA and does not encounter major difficulties in terrain requiring large changes in direction, then the variations in its path will be relatively minor and to a limited extent predictable. Target location/prediction errors can be broken down into two distinct sources.

The first and least significant are the errors projected to the prediction point resulting from measurement inaccuracies as the FO lases on a moving target. The baseline assumptions used to determine the magnitude of the measurement error are given below:

a. The FO lases on a target twice (20-second interval).

b. The target is moving toward the FEBA at 15 km/hr.

c. The response time of the SPH is 66 seconds. (20 seconds to transmit data, compute gun order, lay weapon and fire; 46 seconds flight time.)

d. The laser can determine the target location to within 5 meters $1\sigma$.

e. All error sources are normally distributed.

The geometry of determining measurement error is shown in figure 96. Points A and B of the figure represent the uncertainty of measurement at each location, and the cone represents the maximum $1\sigma$ error boundry. Calculating the downrange and cross-range measurement error standard deviations, represented by $\sigma_{dr}$ and $\sigma_{xr}$ respectively, and converting to CEP by the following relationship:

$$CEP = .24\,\sigma_{xr} + .675\,\sigma_{dr}$$

$$\text{when} \quad \sigma_{xr} / \sigma_{dr} \leq .3$$

$$CEP = .615\,\sigma_{xr} + .562\,\sigma_{dr}$$

$$\text{when} \quad 1 \geq \sigma_{xr} / \sigma_{dr} > .3$$

The resulting error caused by measurement inaccuracies is given as:

$$\text{Measurement } CEP_m \cong 10 \text{ meters}$$

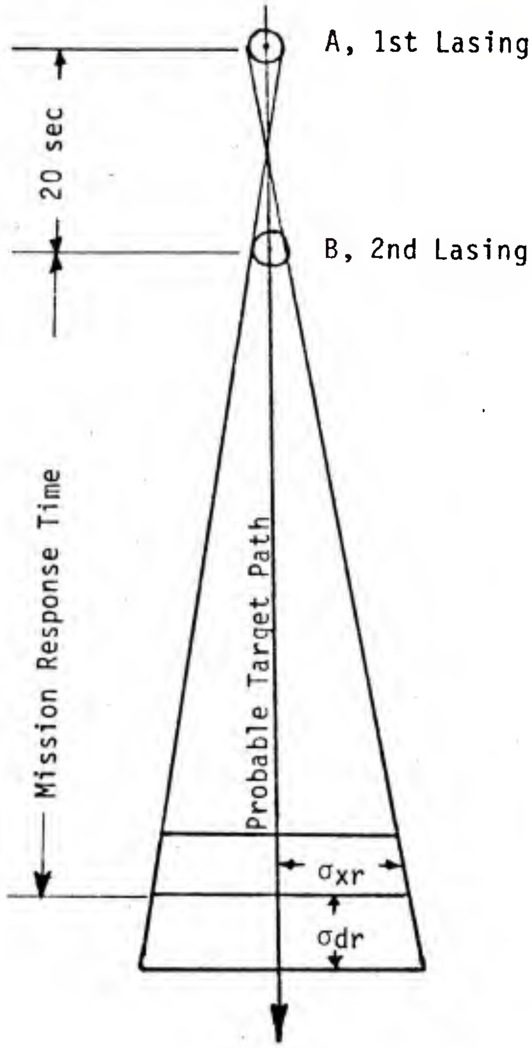



Figure 96 Position Measurement Uncertainty Projected Downrange

The second and major uncertainty involved is the variation in the target velocity vector from final lasing to impact of the round. The geometry of the velocity uncertainty problem is shown in figure 97. Literally, we cannot predict the exact speed and direction of a target after its last position measurement. However, in order to estimate the position of the target at the time the projectile impacts, the following assumptions have been made:

a. The target is proceeding toward the FEBA with a mean downrange veleocity $\bar{V}_{dr}$ and a $\sigma_{vdr} = .2\bar{V}_{dr}$

b. Its mean crossrange velocity $\bar{V}_{xr} = 0$ and $\sigma_{vxr} = .2\bar{V}_{dr}$

c. The time from last lasing to projectile impact is represented by t in seconds.

From the above assumptions we can write

$$\sigma_{vxr} \equiv \sigma_{vdr} \equiv .2\bar{V}_{dr}$$

During the time interval from final lasing until impact of the round in the target area, the target has moved, by the straight line prediction, a distance

$$D_{dr} = \bar{V}_{dr} \cdot t$$

where $\bar{V}_{dr}$ is the mean downrange velocity and t is the response time from final lasing until impact. The mean crossrange distance traveled is, by our assumptions:

$$D_{xr} = O$$

The uncertainty in the position of the target due to velocity variation can be expressed as CEP by:

$$CEP_v = .615\,(\sigma_{vxr} \cdot t) + .562\,(\sigma_{dr} \cdot t)$$

or

$$CEP_v = .24\,(\sigma_{vdr} \cdot t)$$

Since we assumed that $V_{dr} = 15\ km/_m = 4.17\ m/sec$, the target CEP in meters, due to uncertainty of velocity, is approximately equal to the system response time in seconds, or

$$CEP_v\ (m) \cong t\ (sec)$$

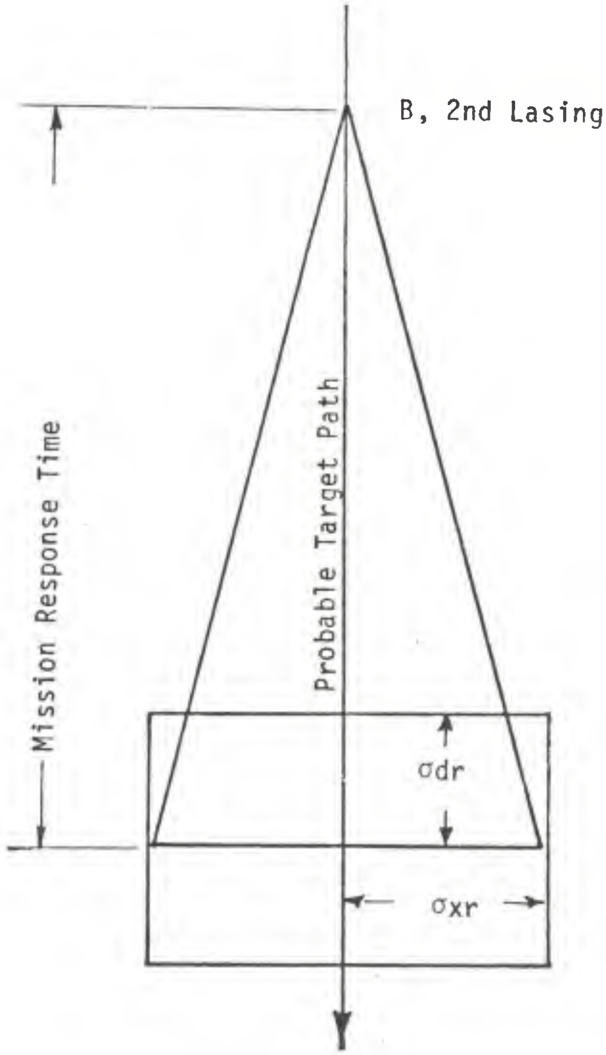



Figure 97 Target Velocity Uncertainty After Last Lasing

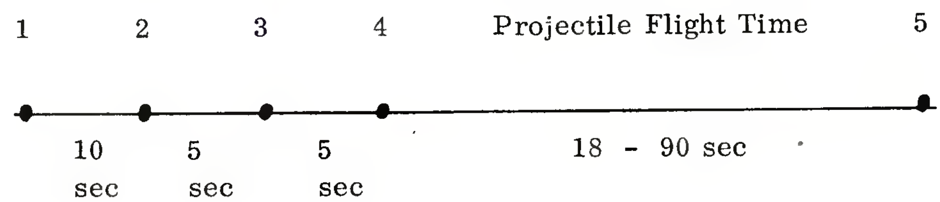
The total $CEP_T$ consists of the two components discussed thus far. Since the component due to measurement uncertainty varies slowly and is small compared to the velocity component, minimal error is introduced by simply summing the two values. Then, for the assumed values,

$$CEP_T \cong CEP_V + CEP_m$$

or

$$CEP_T \cong t + 10$$

It is thus apparent that the target location/prediction errors can be related to the system response time and measurement errors by a rather simple relationship for the assumptions made. The major contributor to the error is the system response time. For our present purposes, response time is defined as the time from the FO's second lasing until impact of the round. This includes automatic message transmissions, computation of the gun order, laying of the gun, and projectile flight time. These times are estimated on the following time line:




1. 2nd lasing

2. End of data transmission

3. End of ballistic computation

4. Weapon layed

4-5. Projectile flight time = 18 sec @ 8 km
= 40 sec @ 14 km
= 58 sec @ 17 km
= 90 sec @ 22 km (est)

The total <u>artillery system</u> delivery CEP for Class II concepts utilizing the HELBAT, ARADS, and MET + VE firing techniques are depicted graphically in figure 98. It should be recognized that these are rough estimates for the simplistic case outlined. However, they are a starting point for a rigorous treatment based on actual map analysis and experimental techniques. The total delivery errors should apply equally to scatterable mines or Copperhead projectiles.

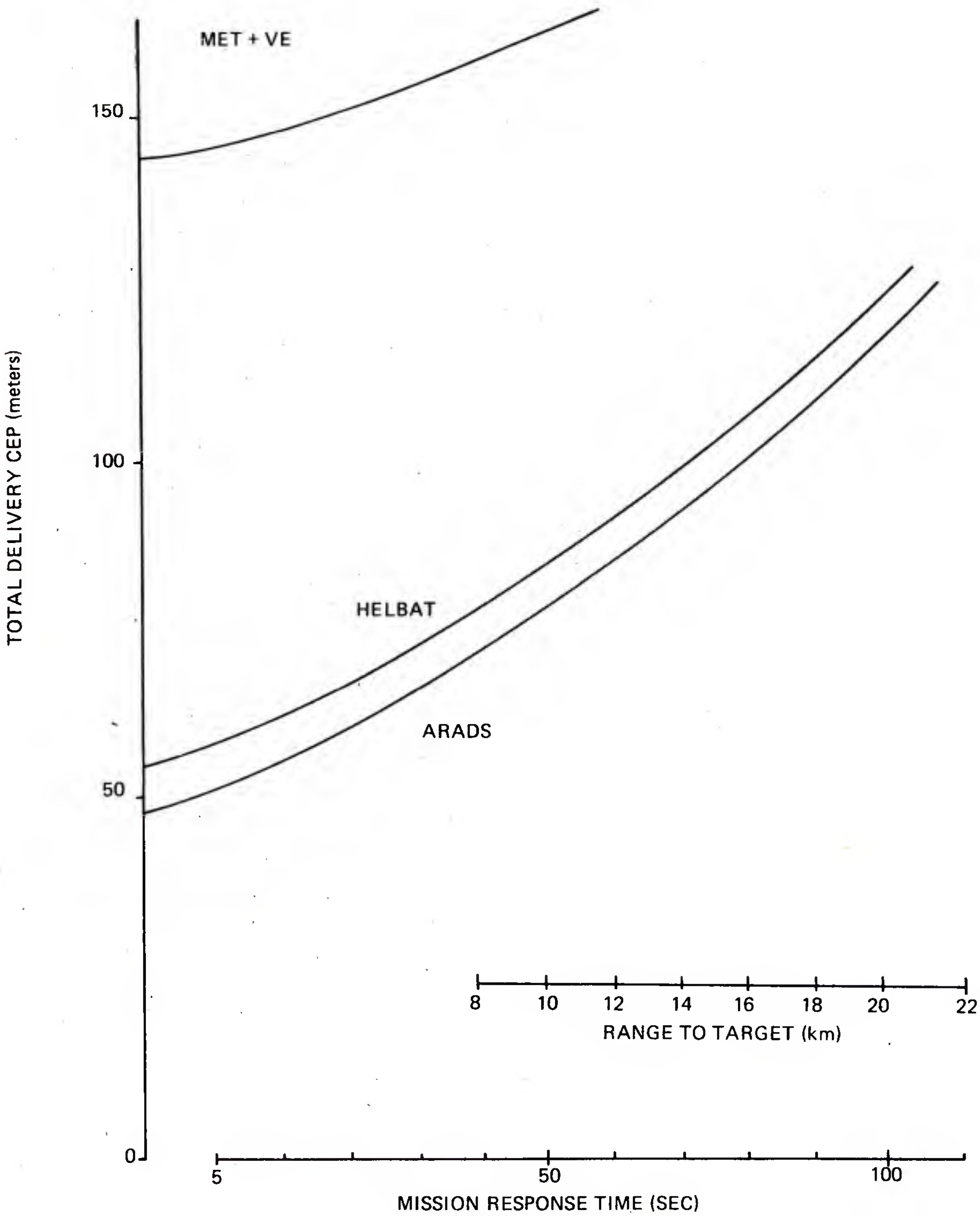



Figure 98 Total Delivery Error Dependance on Mission Response Time and Range

Summary

The problem of providing accurate first-round FFE on a future battlefield has been outlined, and two methods, HELBAT and ARADS, have been discussed. Each has the capability of meeting the accuracy requirements as perceived. However, both are sensitive to target location and prediction errors. As envisioned now, the target location/prediction errors anticipated in the 1985 to 1990 time frame will place the accuracies at the upper limit of the requirement. This, therefore, appears to be an area where improvement would be fruitful.

## LIST OF ACRONYMS

| | |
|---|---|
| AFSM | Artillery force simulation model |
| AGLS | Automated gun laying system |
| AHARS | Attitude heading and reference system |
| APC | Armored personnel carrier |
| ATI | Artillery target intelligence |
| APU | Auxiliary power unit |
| ARADS | Artillery registration and adjustment system |
| ARRADCOM | US Army Armament Research and Development Command |
| ARRCOM | US Army Armament Materiel Readiness Command |
| ARV | Ammunition resupply vehicle |
| ASARC | Army Systems Acquisition Review Council |
| ASES | Artillery system engineering study |
| ASEWG | Artillery system engineering working group |
| ASP | Ammunition supply point |
| ATEPS | Advanced techniques for electrical power management, control, and distribution systems |
| ATP | Ammunition transfer point |
| BCS | Battery computer system |
| BDE | Brigade |
| BN | Battalion |
| BOC | Battery operations center |
| BSTAR | Battlefield surveillance and target acquisition radar |
| CEP | Circular error probability |
| CF | Command fire |
| CFC | Company fire control |
| CLGP | Cannon launched guided projectile |
| CO CMD | Company command |
| CORADCOM | US Army Communications Research and Development Command |
| DEA | Data exchange agreement |
| DMD | Digital message device |
| DS | Direct support |
| DTUPC | Design to unit production costs |
| ECCM | Electronic counter-countermeasure |
| ECM | Electronic countermeasure |
| EMP | Electromagnetic pulse |
| ESPAWS | Enhanced self-propelled artillery weapon system |

| | |
|---|---|
| FASCAM | Family of scatterable mines |
| FDC | Fire direction center |
| FDO | Fire direction officer |
| FEBA | Forward edge of the battle area |
| FRG | Federal Republic of Germany |
| FFE | Fire for effect |
| FIST | Fire support team |
| FO | Forward observer |
| FOV | Field of view |
| FSO | Fire support officer |
| FUFO | Fly under, fly out |
| GLLD | Ground laser locator designator |
| GPS | Global positioning system |
| G/VLLD | Ground/vehicle laser locator designator |
| HE | High explosive |
| HELBAT | Human Engineering Laboratory battalion artillery test |
| HEMTT | Heavy expanded mobility tactical truck |
| HMTT | High mobility tactical truck |
| HOWLS | Hostile weapon location system |
| HTB | Howitzer test bed |
| ICM | Improved conventional munition |
| IFOV | Instantaneous field of view |
| I/O | Input/output |
| IR CLGP | Infrared cannon lauched guided projectile |
| LAP | Load, assemble, and pack |
| LADON | Laser doppler navigation |
| MERADCOM | US Army Mobility Equipment Research and Development Command |
| MET | Meteorological |
| MLRS | Multiple launch rocket system |
| MMBF | Mean miles between failures |
| MPI | Mean point of impact |
| MRBF | Mean rounds between failures |
| NBC | Nuclear, biological, chemical |
| NCO | Noncommissioned officer |
| NCS | Net control station |

| | |
|---|---|
| PLARS/JTIDS | Position location and reporting system/joint tactical information distribution system |
| QE | Quadrant elevation |
| RAM | Reliability, availability, maintainability |
| RAP | Rocket assisted projectile |
| RF | Radio frequency |
| RTS | Remote terminals |
| SADARM | Sense and destroy armor |
| SATCOM | Satellite communications |
| SINCGARS | Smart single channel ground and airborne radio system |
| SOTAS | Standoff target acquisition system |
| SPH | Self-propelled howitzer |
| STANAG | Standardization agreement |
| STE/ICE | Simplified test equipment for internal combustion engines |
| TAB | Target acquisition battery |
| TACFIRE | Tactical fire direction system |
| TARADCOM | US Army Tank Automotive Research and Development Command |
| TDMA | Time division multiple access |
| TLE | Target location error |
| UHF | Ultra high frequency |
| UK | United Kingdom |
| VE | Equivalent velocity |

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